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Connecting the dots : playful interaction with scientific image data in repositories

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Connecting the Dots

Playful Interactions with Scientific Image Data in Repositories

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Chapter 1

Introduction

1.1 Introduction (of the introduction...)

This work is about playful exploration of scientific image data in repositories. In particular, it considers playful interactions with image data from the life sciences stored in well-maintained, shareable image collections. Given the key role of images in biological research and the potential of well-maintained data repositories as sites of discovery, we are enthusiastic about the ways that interacting with image data in collections could inform the research process. Considering also the creative nature of scientific inquiry, we ponder on the types of interaction that could transform data repositories into playgrounds for scientific creativity. Interfaces to scientific image collections should foster the conditions for creative insights into one's own data, often under the light of other data and/or due to connections or associations reached. We will argue that such re-considerations of image research material could be stimulated by creating opportunities to literally play with images in repositories. Artefacts, i.e. interfaces, to exemplify and further study this notion of play for exploration are designed, developed and analysed.

This thesis is a response to context, reviewed literature and current developments in Human Computer Interaction (HCI). But the fact that you are now reading this particular response and none other is also because of own my personality and my own views, likings and dis-likings. I am of the opinion that to be productive does not always mean to be efficient. I also believe that getting lost or simply wandering is a valid way to knowing. Finally, I do maintain a soft spot for links, connections, associations, gaps to be filled in and spaces in between. That said, be assured that having preferences does not imply that the regarded

topics are unsupported in the literature or unrelated to the aims and scope of the project in question; it does mean, however, that I was attracted to study them.

For the past four years, the author of this work has been struggling with concepts that stubbornly defy definitions (e.g. creativity), a common consensus (e.g. play) or a measurable outcome (e.g. exploration). This introductory chapter pins down the fundamental concepts involved in this body of work, examined under the lens and interests of this exact body of work. While no finite definitions will be attempted, a common ground in terminology and sufficient knowledge of the context of our work should be attainable. Our idiosyncratic understanding of the concepts involved as utilized throughout this thesis will also be highlighted.

1.2 On the use of images in (life) science

It all started with an image database for the life sciences. As a scientific programmer with the task to develop the web interface of the CSIDx repository (Cyttron Scientific Image Database for eXchange), I was very comfortable with concepts such as data, records and databases. However, and in the course of time, it was moving to realize how involved biologists are with their images. For a biologist, an image is just not another entry in a database; it is science.

image: *A visual entity or rendering initially captured by means of a sensor of an imaging technology*

For the purposes of this study, images can be understood as visual entities or renderings that were initially captured by means of a sensor of an imaging technology, e.g. a microscope. Our definition has been influenced by the views of imaging science as the study of images and imaging systems; after all, this research has been conducted in an imaging group of a computer science department. Beck (1993), pioneer of imaging science, explains that

> "images (including the imperfections introduced by the imaging system) may be characterized by the spatial (and possibly the temporal) distribution of properties such as light reflectance, color, brightness, or opacity/transmittance at each point- i.e., by the numerical values associated with such properties".

As such, images are registered values of some captured physical property that are rendered visible. Surely, a variety of algorithms and processes may interfere between the moment the captured energy excites the sensor and the moment a visualization is produced. Yet, we still refer to these visualizations as 'raw' images

which can be further used for image processing and analysis. Considering the variety of visual representation used in scientific practice, our definition of images explicitly excludes graphical compositions such as illustrations, graphs and diagrams, all most likely to be assembled by a human agent. These diagrammatic or graphical displays are essential in conducting science but are rarely perceived as 'raw' data by the researchers, although advanced imaging techniques such as spectroscopy may challenge this distinction. The diversity of visual representations involved in scientific practice as well as the aspects that contribute to this diversity are thoroughly addressed by Pauwels (2008). With respect to his proposed framework, our understanding of images emphasizes algorithmically derived representations of subjects with a physical presence in the natural world.

The predominance of images in science often goes without saying. And, as most things that go without saying, it becomes cumbersome to trace or verify, once questioned. How are images actually used for conducting science? As already noted by Pauwels (2008), visual products must be examined with respect to their purpose. The author proposes a non-exhaustive list of possible usages and intents, including further analysis, concept development, result communication, persuasion and many more. In this study, we focus on the needs and practices of scientists engaging with biological research. Biologists, life scientists and, occasionally, bioimage informaticians are the featuring personas of this discussion. So, let us rephrase the question: How are images used for conducting science in the field of biological research?

Biological research provides an excellent example of the predominance of images in scientific inquiry. What Schaechter (2008) and Kemp (2008) describe as the 'visual turn' in microbiology is relevant to most disciplines engaging with the study of life. The production, inspection and analysis of image-based observations is an indispensable part of contemporary biological research, from molecular biology to cell biology to organismal biology. Imaging has also a major role in medical practice and research but the practices of a clinician will differ from the practices of a researcher imaging a model organism or postmortem tissues in a research lab, even if the same imaging technology is involved. An indication of the variety of imaging techniques used in biological research and of the wide field of research topics for which imaging is relevant can be found in Conn (2004a,b). Walter et al. (2010) provide an informative and up-to-date overview of the practices, challenges and trends involved in the use of image data in contemporary biology, including high-throughput imaging. More applications of bio-imaging and more computational challenges are discussed in Peng (2008). Naturally, the explosion of image data produced during biological research poses pressing demands for robust sys-

tems and for standardized practices for the storage, retrieval and sharing of these data. We will further discuss data management issues in chapter 2, where the CSIDx database system is described in depth. All in all, it should be clear that images have a central role in contemporary biological science. In the words of Evanko (2010), editor of 'Nature Methods', "biology is a visually grounded scientific discipline- from the way data is collected and analysed to the manner in which the results are communicated to others".

From the variety of functions and roles of images in the research workflow and scientific discourse of the biologist, we will mainly focus on images as primary data to be further analysed by human inspection. Based on our experience with collaborative, imaging projects with researchers in the life sciences, we adopt the following, simplified take on biological imaging for research purposes: Biologists make images in order to study biological phenomena; they design experiments and image their samples in order to test hypotheses, to track biological entities or processes or to model test organisms. Image data are to be observed, discussed, reflected upon and further tested by designing new or refined experiments. Note that the processes involved are primarily social and collaborative. They may also require comparing or contrasting the acquired image data to other reference images. Via such processes, image data become significant signposts in directing research and decision-making. Then again, for discoveries to be made, images need to be quantified: It is unlikely that a discovery will be granted on the basis of visual evidence only. Thus, we see image-based observations as an intermediate but fundamental step in the process of scientific inquiry. Eventually, and once discoveries are made, images will be turned into communication tools, functioning as the means to communicate findings to fellow scientists.

A word of caution is now due. Generally speaking, visuals in sciences are treated as evidence of credible persuasive power. Yet, their objectivity should not be taken for granted. This remark does not attack the scientific integrity of practising scientists but is a reminder of the constructed nature of scientific images and of the often unsaid assumptions of scientific practice. Historians of science, sociologists of science and philosophers of science have led the discussion on the risks of uncritically accepting visuals and images as objective representations of nature. Lynch (1988), Knorr-Cetina and Amann (1990) but also Kemp (2006), among others, have examined the practices involved in the production of scientific imagery. Regarding the images featuring in this work, it is worth remembering that computer-generated imagery is not free from inscribed decisions, often hard-coded in the algorithmic system involved, despite its seemingly 'self-evident' nature. On the contrary, and possibly even more that any other type of visuals,

images resulting from algorithmic processes challenge the relation between the subject depicted and the visualization rendered and exploit our susceptibility to visual evidence. Eventually, visual studies will have a saying in the type of discourse that is unconsciously implied or deliberately communicated by the use of images in scientific communication. While a complete examination of the philosophical implications of image-based science is out of the scope of this work, we feel that any work that deals with scientific images should at least acknowledge the issues.

So, images are fundamental and frequent in the process of biological research, but where do these images actually reside? One will find biological images of non-finalized research residing on the hard disks of researchers, circulating around the corridors of research institutes and laying on the tables of research meeting rooms. Occasionally, they find their way into databases.

data repository, data collection: *A structured set of entities (e.g. images) available for access and distribution*

Scientific practice is the yet another human activity that accumulates data; if not the chief one. Apart from any epistemological implications involved in our society's need to accumulate data in repositories, structured collections have straightforward practical benefits for managing and sharing research data. For the purposes of this study, a data repository (also referred to as data collection) is a structured set of entities/tokens of information available for access and distribution. Clearly, our interest lies in collections of images of a biological subject matter. In the life sciences domain, the '-omics' revolution has familiarized biologists with the need to access large volumes of well-maintained data. An impressive number of databases for biological purposes have spawned in the last couple of decades; see Chiang (2004) or the inventory of database resources maintained by the prestigious 'Nucleic Acids Research' (NAR) journal. Image databases are yet to reach a similar status of popularity. Martone et al. (2007) suggest that image databases are yet to become useful and meaningful for biologists because of the computation difficulties in the analysis of image data. Nonetheless, significant biological image database projects exist. We acknowledge the need for image data to be stored in well-maintained repositories and endorse the benefits for biological discovery as described by Swedlow et al. (2009), i.e. management, sharing, remote access, interoperability and integration. However, in the research described in this thesis, we wish to shift focus from the practical benefits of image repositories and discuss the benefits of a well-maintained image repository in terms of its potential to stimulate scientific creativity.

1.3 Why exploration?

The first proposition of this study is that exploration as an open-ended information activity can be beneficial for scientific practice for it can excite the small discoveries and insights that fuel scientific creativity. This section will overview various aspects of scientific creativity (cf. subsection 1.3.1) and of discovery in data repositories (cf. subsection 1.3.2) that motivate and inform our appeal for exploration. The open-ended, exploratory, possibly procrastinating interaction we are after should be crystallized by the end of this section; for lack of a better term, we abbreviate it as exploration.

1.3.1 On scientific creativity

Science is a creative endeavour. No doubt scientists regularly "come up with ideas or artefacts that are new, surprising and valuable", conforming to most definitions of creativity. The quoted fragment is derived from Boden (2004, chapter 'In a nutshell') and her definition of creativity as "the ability to come up with ideas or artefacts that are new, surprising and valuable". Similarly, Sternberg (1999, chapter 1) defines creativity as "the ability to produce work that is novel and appropriate". While the qualifiers given deserve further consideration, it is clear that such definitions of creativity are inclusive of the fruits of science, i.e. scientific theories and scientific discoveries. Even more importantly, science is a creative endeavour because scientists will often need to resort to creative thinking when weaving their way through research. Scientific practice, including both the formulation of worthwhile problems, i.e. problem-finding, and the struggle to solve them, i.e. problem-solving, frequently calls for the scientist's creative toolbox. There is nothing mystical or romantic here, no muse visitations or bursts of inspiration: Scientific practice is creative for it "involves slow, methodical work, with mini-insights occurring everyday" (Sawyer, 2006, chapter 14). Such mini-insights vary from new ideas to new observations to new realizations and new inferences and may be based on or derived by scientific data.

Creativity is a complex phenomenon. It is notoriously difficult to define, has multiple aspects, i.e person, process, press, and product (Rhodes' scheme, discussed in Runco, 2004), and can be researched via various methodologies, from psychological to biological to computational. Mayer (1999) provides a good overview of the various research streams in creativity research, while Kozbelt et al. (2010) summarize some of the most prominent theories of creativity. We tackle only a small portion of the phenomenon, i.e. creativity as a property of thinking (Nickerson, 1999), and observe that creative thinking as both the capacity to gen-

erate ideas and "the capacity to bring together previously unconnected 'frames of reference' " (Nickerson, 1999) is relevant for everyday scientific practice. Some of the processes that appear to be involved in the cognition of creative thinking, such as synthetic and analytic thinking, remote associations and concept combination, among others, include a notion of synthesis by links and associations which we find particularly relevant.

What exactly is the relation between scientific creativity and scientific discovery? Some scholars seem to use the terms interchangeably (see e.g. Meheus and Nickles, 1999); after all, they both refer to the production and recognition of something new and valuable. Others suggest that aspects of the process of scientific discovery may be performed creatively. To quote Langley (1987, chapter 1), "we have characterized discovery as a sequence of steps, each of which represents a small advance from an initial state of knowledge to a new state of knowledge and all, some or none of which, taken individually, might seem creative". Most likely, it is again a matter of one's preferred view on creativity and/or discovery.

The cognition of scientific discovery is equally fascinating and puzzling. The phenomenon of scientific discovery has been argued by both cognitive scientists and philosophers of science. Once again, the approaches taken in researching scientific discovery vary. An overview and comparison of research methodologies and of prominent theories is provided by Klahr and Simon (1999). How scientists discover and how scientists reason are two distinct but overlapping questions. An introduction to the broader topic of scientific thinking and reasoning is provided by Dunbar and Fugelsang (2005). Of particular relevance to the scope of this thesis is the *in vivo* research of Dunbar (1995) on scientific reasoning. The author monitors real-world laboratories, in particular molecular biology laboratories, to comment on the mechanisms active during scientific practice. His research highlights, among others, the importance of analogy, which he further distinguishes to local, regional and long-distance analogy, and the importance of social interaction within a research group.

An illuminating study on the topic of scientific creativity with respect to information systems is given by Bawden (1986). The author identifies topics related to scientific creativity that can be coupled to issues of access to information. Both the type of information required and the means to it are discussed. His observations on the nature of scientific creativity, namely

- the role of chance
- the value of analogies
- the importance of identifying inconsistencies and anomalies in patterns
- the damaging effect of false knowledge

- the value of interdisciplinary contact

have shaped our understanding on how creativity may inform scientific research. Furthermore, we are confident that activities such as "the relating of ideas generally held to be quite distinct" and "the recognition, or creation, of patterns" can potentially be stimulated by exploring data in repositories. The role of connections is also prominent in O'Connor (1988) and his examination of creativity in bibliographic systems. The author views creativity as a process of "reconciliation or reformulation" of existing concepts into new ones. As such, the creative process can benefit from a "readiness for catching similarities" and from openness to free associations, even illogical ones. The author also discusses creative browsing as navigation for "the discovery of new knowledge, of new syntheses" which he relates to three different types of connections:

- connections between 'attributes of documents'
- connections between 'concepts in the user's knowledge store (with document attributes as catalyst)'
- connections between 'the user's concepts and attributes of documents'

The production of new knowledge by a synthesis of existing concepts as facilitated by data in collections will be central in our approach.

Next to the domain of information sciences, the field of HCI has also been attentive to issues of creativity with respect to computer interfaces. Shneiderman (2007) notes that the new challenge for HCI researchers and interface designers is to design tools that support creativity, discovery and innovation. More specifically, the author is calling for tools that will be supportive of the cognitive processes involved in the creative process. As a matter of fact, Shneiderman (2000) proposes a four- stages framework for the 'generation of excellence': Collect (existing knowledge), relate (with peers), create (potential solutions), donate (results). His framework and similar others (e.g. Hewett, 2005) focus on creativity as a problem-solving process often to be facilitated in its entirety by a computerized platform. Our research scope is far less ambiguous. We note, though, that some of the activities Shneiderman (2000) proposes as worthwhile, namely searching and browsing digital libraries, visualizing data and processes and thinking by free associations, are directly related to interacting with data in repositories.

1.3.2 On small discoveries and insights

to discover: *to arrive at something (item, association or realization) that is new or interesting*

Science is all about discoveries but we confine our discussion to the small discoveries and insights that can be facilitated by data in repositories. In the context of data repositories, we understand discovering as arriving at something (item, association or realization) that is new or interesting. Discoveries in repositories may occur at various levels:

- At the item level, when reaching a valuable, interesting or unexpected item or entry
- At the association level, when establishing a new or thought-provoking connection between items
- At the dataset level, when making assessments about the whole of a dataset

Any of these small discoveries may inform the process to actual scientific discoveries. Many of these discoveries can be understood as serendipitous, either in the sense of being accidental (what van Andel (1994) calls an 'unsought finding') or in the sense of being surprising. Since much has been said about the role of serendipity in scientific discoveries, let us further examine the notion of serendipity with respect to information systems.

There is a nice and often-repeated story on the origins of the word 'serendipity' (van Andel, 1994): English writer and man of the letters Horace Walpole coined the word 'serendipity' in 1754 in one of his letters to Horace Mann, British diplomat with whom Walpole maintained correspondence for 45 years (Encyclopædia Britannica Online, 2012b). The word was inspired by the adventures of 'The three princes of Serendip', the heroes of a Persian fairytale who were travelling the world making "discoveries, by accidents and sagacity, of things which they were not in quest of"[1]. Generally speaking, serendipitous discoveries are discoveries not looked for. However, 'discoveries not looked for' come in many flavours: There are things to be found at unexpected moments or places, there are unexpected (odd and surprising) things to be found and there are unexpectedly valuable things to be found. Foster and Ford (2003) observe that a feeling of serendipity stems from either the impact of new information, i.e. due to unexpected value, or the chance encountering of information, i.e. due to unexpected location. Moreover, van Andel (1994) highlights that serendipity appears either as a surprising fact/relation, that may lead to insight, or as a surprising way to reach insight (pseudo-serendipity). The positive role of serendipity in the creative process is well-articulated and so is the need to consider serendipity within digital information systems. In information retrieval (IR) literature, browsing is considered the typical information

[1] A part of the story that often goes unsaid is that Walpole invented the word 'serendipity' in need to describe his own small serendipitous discovery.

behaviour for serendipity; we elaborate on the characteristics of browsing in the next subsection. Serendipitous information retrieval is also examined in the work of Erdelez (1999) on 'information encountering', the work of Toms and McCay-Peet (2009) on 'chance encounters' and the work of Williamson (1998) on 'incidental information acquisition'. These studies remind us that there exist valued information behaviours that differ from traditional information seeking. Serendipitous information retrieval often centres around the notion of chance, blind luck or even pure randomness but chance is only one part of the story. As van Andel (1994) emphasizes, for serendipity to be meaningful, a successful abduction must be reached. Similarly, André et al. (2009) note that if we are to support serendipity in information systems, we must consider the processes that govern a successful response to an unexpected finding, i.e. the processes that allow one to connect the unexpected finding to the relevant problem or to already available pieces of information. In our work, we welcome the idea that discoveries do not necessarily arise from searching and remain attentive to options other than simple exposure to chance encounters.

And what about 'insights'? Strictly speaking, an insight is a discovery characterized by suddenness or "the experience of suddenly realizing the solution to a problem or of grasping a familiar situation in a new or more productive way" (Nickerson, 1999). Schooler et al. (1995) observe two different usages of the term 'insight' in the cognitive sciences as either a "state of understanding" or "a sudden emergence of an idea into conscious awareness". The field of information visualization, a field dedicated to gaining insight over data, takes a more casual view on insight as a "unit of discovery" and as "a non-trivial discovery about the data or, as a complex, deep, qualitative, unexpected, and relevant assertion" (Yi et al., 2008). Insight is frequently associated with a notion of reformulation. In the cognitive sciences, it is often suggested that insight may arise from a restructuring of the problem's representation. Davidson (1995) proposes the following possible mechanisms of problem restructuring:

- Selective encoding, i.e. the identification of non-obvious features
- Selective combination, i.e. the combination of elements in non-obvious ways
- Selective comparison, i.e. the establishment of non-obvious relations between new and past information

Information visualization literature also hints at a similar aspect of reformulation or, to quote, "suddenly seeing something that previously passed unnoticed or seeing something familiar in a new light" (Saraiya et al., 2005).

Reaching unexpected but useful items or reaching useful items unexpectedly (serendipity), establishing associations between items (connections), making assessments about a dataset as a whole (patterns), re-viewing or re-considering an item under a new light (insight), these are only a few of the ways that interacting with data in collections can promote understanding, fuel creativity and inform everyday scientific practice. It is such small increments in understanding that our 'small discoveries and insights' refer to.

1.3.3 Exploration as an open-ended information activity

If data repositories hold a multiplicity of opportunities for small discoveries, what kind of tools will we need to actually mediate them? This is a battle that can be fought at many fronts. We believe that, when interacting with data in repositories, discoveries can be stimulated by means of the interface. That is to say that, next to the sustainable body of research to improve the underlying representations and access mechanisms to data, e.g. content-based image retrieval, clustering and classification, knowledge discovery, semantic reasoning and more, the interfaces that provide access to the repositories should also be considered. Not only do we need usable, well-designed interfaces for the user to make the most out of the capacities of the repository. We also need interfaces that will encourage and engage the user to explore.

The aim of this study is to design interfaces to data collections that will nurture the conditions for small discoveries, insights or creative responses to occur, always in the context of data collections and within the broader frame of scientific practice. In the previous subsections, we encountered several elements of creativity and discovery that share a notion of establishing associations between existing concepts or between existing and new/newly encountered concepts. Furthermore, we identified various activities with data that can be of relevance for scientific creativity:

- Reaching unexpected but useful items or reaching useful items unexpectedly (serendipity)
- Establishing connections between items (connections)
- Making assessments about a dataset as a whole (patterns)
- Re-viewing or re-considering an item under a new light (insight)

Note that none of these activities corresponds with query-based search and fact-finding. Most lack an explicit goal or information need and some imply a notion of movement across information points. Within the field of IR, strategies such as browsing, exploratory search and the use of information visualizations

for IR are successful examples of interactions that differ from the predominant keyword search paradigm.

Browsing: Browsing is a major information seeking strategy that is distinct from keyword search. Most definitions of browsing stress its casual and exploratory nature: Baeza-Yates et al. (1999, Glossary) define browsing as an "interactive task in which the user is more interested in exploring the document collection than in retrieving documents which satisfy a specific information need", while 'to browse' according to Reitz (2012) is "to look through a library collection, catalogue, bibliography, index, bibliographic database, or other finding tool in a casual search for items of interest, without clearly defined intentions". A comprehensive survey of various understandings of browsing is provided in Chang and Rice (1993), while differences between browsing and keyword searching are summarized by Hearst (2009, chapter 3). It is useful to repeat here that browsing is often undirected, i.e. without a clearly defined goal. For example, Bawden (1986) reports two undirected types of browsing, namely 'capricious' browsing as "the random examination of materials without a definite goal" and 'exploratory' browsing as the search of inspiration.

Exploratory search: Exploratory search is a search paradigm that emerged out of the need to facilitate information needs of an "open-ended, persistent, and multi-faceted" character (White and Roth, 2009). In particular, exploratory search targets searches of a high degree of uncertainty, when searchers are "unfamiliar with the domain of their goal or unsure about the ways to achieve their goal. . . and/or even unsure about their goals" (White and Roth, 2009). Successful implementations of the exploratory search paradigm can be found in faceted search, i.e. search by combination of known, usually hierarchical metadata of a dataset, and in dynamic queries, i.e. search that allows direct manipulation of a visual representation of the dataset. More examples are discussed in Crawford (2006). Exploratory search, as envisioned by Marchionini (2006), is relevant for it reminds us that searches are not conducted only for question answering but also for learning and investigation. What is more, it promotes a cooperation between information retrieval and the field of HCI toward interfaces that would better cater for these needs.

Information Visualization and IR: Information visualization, as "the communication of abstract data. . . through the use of interactive visual interfaces" (Keim et al., 2006), provides a considerable solution to the problem of information

overload and a valid way to amplify understanding by using the visual capacities of humans. If we describe data repositories as nominal datasets, then data repositories are valid subjects for visualization; typical information visualization tasks will support manipulation and exploration of the dataset. If we approach data repositories as IR systems, then information visualization is again of relevance. As noted by Song (2000), all components of a traditional IR system can be presented visually, from the user data to the query to the query results. Additionally, various user tasks in interacting with the IR system can be visually facilitated, from goal-setting to querying to evaluating results. The visualization of search results has received considerable attention particularly with respect to web search. Kules et al. (2008) identify several design patterns in visualization-based web search tools, such as classification (hierarchical, faceted, automatic or social), results organization (in lists or in 2D and 3D space) and several more. More web- and visualization-based systems are reviewed by Turetken and Sharda (2007). Most IR-related visualizations are not limited to a static presentation of the result sets but also provide the visual means for query formulation and reformulation, for navigation and/or for browsing.

to explore: *to examine and investigate data, their location and their properties, may potentially stimulate small discoveries and insights*

The aforementioned strategies, i.e. browsing, exploratory search and the use of information visualizations for information retrieval, have informed our understanding of exploration in the context of data repositories. In particular, we envision interactions that are of an open-ended and casual nature (cf. browsing) yet combined with an alert consideration of entities, their attributes and the structure they belong to (cf. information visualization). What is more, we deliberately sheer away from searches (cf. exploratory search) and consider ways to engage with data that stem from notions of associations and reformulations, as also motivated by cognitive aspects of creativity, discovery and insight. Although we acknowledge the role of browsing and navigation, we emphasize that insights and discoveries occur not by simply visiting or encountering entities but when reconsiderations or useful associations are reached.

Common understandings of exploration, i.e. outside of the domain of IR, are also worth mentioning. Stebbins (2001) discusses four distinct meanings of the verb 'to explore' which he couples to distinct types of exploration [2]:

[2] Stebbins (2001) examines 'exploration' in order to better understand the exploratory research paradigm in the social sciences. Exploratory research is a particular research methodology which should not be confused with the practices proposed here. Nevertheless, the author's observations on the usage of the word 'exploration' are relevant.

1. Investigative exploration, when studying, examining, analysing, or investigating something
2. Innovative exploration, when becoming familiar with something by testing its properties
3. Exploration for discovery, when travelling for the purpose of discovery
4. Limited exploration, when searching systematically for something

We consider the exploration of images in the investigative sense and the exploration of repositories as exploration for discovery. In fact, a spatial metaphor for data repositories can provide us with a useful mental model. Data collections are information spaces to be travelled and explored. On the way, and by investigating data, their location and their properties, discoveries and insights may occur. Furthermore, we expand this spatial metaphor by emphasizing that insights and discoveries occur not by simply visiting entities but when reconsiderations or useful associations are reached.

1.4 Why playful?

An invitation to play is an invitation to explore. Or is it vice versa? Play and exploration are concepts so intertwined that, at moments, we wonder if we have been trapped in yet another chicken-or-egg question: Does one explore when playing or play when exploring? As far as this study is concerned, it is sufficient to acknowledge that play and exploration both feed and nourish each other. Play as exploration and exploration as play maybe just two expressions of what one could describe as adopting a playful attitude. Playfulness can be understood as the inclination to be less serious and more experimental; as such, it caters for the open-mindedness we find essential when exploring in collections. Playfulness as curiosity or the ability to toy with options and alternatives is also a highly desirable attitude. Finally, playfulness as simply playing and enjoying is equally desirable even if it is only for reasons of engagement with the task.

The second proposition of this study is that designing for play and playfulness is a valid way to design for exploration. As a matter of fact, we will take this idea literally: Playing with data in collections is a means to exploring data in collections. In effect, our work attempts to enrich our interactions with images by incorporating aspects of play. Our initial orientation towards play has been driven by notions of exploration: Openness, playfulness and positive affect are essential components of an attitude that favours exploration. Yet, our orientation towards play and our take on playful and game-like interfaces have sprouted amid

a fast-growing interest of the HCI community in play and playfulness. As we shall see, this work is not the first one to propose a pollination of interfaces with ideas from play and games. Still, we approach, study and prototype this concept from within a particular domain, i.e. interfaces to scientific image collections, and with a particular agenda, i.e. collection exploration. What is more, we have been open to various modes of play and examined a wide range of what game-like or playful interfaces to collections may be like. In the following chapters you can find out what happens when an HCI researcher with a particular agenda messes with the idea of play. For now, let us provide a necessary context by summarizing views on play as derived from the field of game studies and views on the closely related issues of fun and pleasure. But mainly, let us expand on the meeting points of such topics with HCI and interface design.

1.4.1 Homo ludens: The fundamentals

Delineating the notion of play is a difficult task and any attempt to do so will unavoidably start from the seminal writings of Johan Huizinga (1842-1945) (Encyclopædia Britannica Online, 2012a) and Roger Caillois (1913-1978). Note that there is an overwhelming body of research on children play which we will not consider here; our focus is on attempts to formally define the notion of play.

Huizinga was one of the first theorists to consider the significance of play for human culture. In his classical work "Homo ludens" (translated as "Man the Player"), Huizinga (1955, chapter 1) provides the following, widely cited and argued, list of characteristics to define play:

> "Summing up the formal characteristic of play, we might call it a free activity standing quite consciously outside 'ordinary' life as being 'not serious' but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings that tend to surround themselves with secrecy and to stress the difference from the common world by disguise or other means".

Caillois's equally influential work "Les jeux et les hommes" (translated as "Man, Play and Games") lists a comparable set of characteristics. Play, according to Caillois (2001, chapter 1), is an activity that is

- free, i.e. not-obligatory

- separate, i.e. circumscribed in time and place
- uncertain, i.e. with unforeseeable outcome
- unproductive, i.e. creating neither goods nor wealth
- governed by rules, i.e. with rules that are different from everyday life
- make-believe, i.e. accompanied by the awareness of a different reality

Caillois (2001, chapter 2) further suggests that play activities span across a continuum between two types of play, namely ludus, i.e. ruled-governed activities, and paidia, i.e. improvised activities. The voluntarily and self-fulfilling nature of play is an element reoccurring in various writings and theories about play. Walther (2003) summarizes Gregory Bateson's theory of play and fantasy as follows: "Bateson further states that playing is autopoietic (self-generating) and autotelic (self-motivating), and finally he suggests that play is not the name of some empirical behaviour, but rather the name of a certain framing of actions". We will return to this idea of framing when considering 'playfulness' as a state of mind.

Discussions on the notion of play are soon followed by discussions on the notion of game. What is a game and how does it compare to play? Loosely speaking, a game is play that is structured and goal-oriented. But scholars in the domain of game design, the core subject of which is games and play, have more to comment about. Juul (2005) proposes a classical game model according to which a game is:

- a rule-based formal system
- with variable and quantifiable outcomes
- where different outcomes are assigned different values
- where the player exerts effort in order to influence the outcome
- the player feels emotionally attached to the outcome
- the consequences of the activity are optional and negotiable

Definitions are to be debated and expanded; and they are meant to leave some scholars unsatisfied. As this work is not about formally defining the notions of play or game, we will gladly adopt the definitions provided by Salen and Zimmerman (2004). The authors compile and compare both the common language usages and the major formal definitions of play and game. Eventually, they propose the following definition of a game (digital or other):

> "A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome".

Interestingly, the authors suggest two possible relationships between the notion of games and play: Games as a subset of play activities, in one hand, and play as a component of games, on the other hand. Confronted with the ambiguity of play, the authors propose three families of activities, each a superset of the previous:

- Game play, i.e. activities that involve games as described above
- Ludic activities, i.e. activities commonly understood as play
- Playful activities, i.e. ordinary activities exercised in a playful manner

Eventually, they propose a definition of play as

> "free movement within a more rigid structure".

This definition, complemented with the above-mentioned families of play-related activities, should provide a sufficient framework for the purposes of this thesis.

playfulness: *the inclination to be less serious, i.e. more humorous, or more experimental or looking for fun and amusement*

The proposition that play emerges out of a playful attitude rather than out of specific characteristics of an activity is particularly interesting. Playfulness can be understood as the inclination to play; as such, however, it does not further contribute to our discussion about play. Seen as the inclination to be less serious, i.e. either more humorous or more experimental or looking for fun and amusement allows us to reconsider what engaging in play may amount to. To quote Fullerton et al. (2008, chapter 4), "a playful approach can be applied to even the most serious of difficult subject because playfulness is a state of mind rather than an action". Note that we consider playfulness as an attitude, not as a personality trait, and one that can be induced. We will be using the term 'playful' as in playful interface/playful interaction to refer to interfaces that are both an invitation to play and an invitation to adopt a playful attitude. However, it should be mentioned that the notion of 'playful interfaces' is not without its cultural baggage within the field of HCI. Kuts (2009) reviews HCI literature on 'playful interfaces' and reports the following notion of playfulness within HCI: "The definition of playfulness in user experience can be crystallized as elements of a design that engage people's attention or involve them into activity for play, amusement, or creative enjoyment". Identified aspects of playful interfaces are, among others, creative enjoyment, exploration, customization, curiosity, fantasy and metaphor.

Not surprisingly, most understandings of play and playfulness assume some sort of satisfaction or pleasure involved. Positive emotions such as fun, amusement, joy, delight are often associated with play and playfulness. We can fairly

assume that play pleases us but how exactly play pleases us is a subject of further study. Costello and Edmonds (2007) propose a framework of thirteen pleasure categories of play, namely creation, exploration, discovery, difficulty, competition, danger, captivation, sensation, sympathy, simulation, fantasy, camaraderie and subversion. While particular to playful interfaces in the context of interactive art, their framework provides a useful synthesis of various theories on play and pleasure experiences. Korhonen et al. (2009) propose a 'Playful Experience framework' of twenty playful experience categories validated versus the subjective experiences of video game players. Coming from a game design perspective, Hunicke et al. (2004) propose a vocabulary of eight kinds of fun to describe the fun in playing games, namely sensation, fantasy, narrative, challenge, fellowship, discovery, expression and submission. Finally, the highly influential work of Csikszentmihalyi (1975, 1991) on flow, i.e. a state of absolute absorption in an activity, and his model of flow state as a balance of skill and anxiety have been repeatedly applied to explain the experience of a player as well as to guide game design.

In the next section, we further examine the notions of fun and enjoyment from an HCI perspective.

1.4.2 HCI ludens: Intersections and cross-pollinations

The rise of the enjoyable interface

Is playfulness and enjoyment relevant for HCI? In 1988, this suggestion might have been considered a joke: "Fun" is a 1988 SIGCHI bulletin article by Carroll and Thomas (1988) discussing the importance of fun for human computer interaction. In fact, it is one of the pioneering calls within HCI to seriously study the impact and nature of fun. The authors of the article end their discussion with the following contemplation: "We realize that many people will read this article as a sort of joke. To this extent, we are the victims of our own analysis: there are risks in being serious about fun". Today, it is well-acknowledged that HCI needs to seriously take fun into consideration.

The reasons for HCI to research fun have been multiple. Consider for example, the three cases identified by Draper (1999) when fun is actually a software requirement:

- Software with fun as the main function
- Software with learning as the main function
- Software with high learnability requirements

From 1999 onwards, Draper's cases have become increasingly relevant. It has been often remarked that, as technology moves from the workplace to everyday life, including leisure and entertainment, the design of products or experiences must deal with issues of fun, enjoyment and pleasure. On the other hand, many scholars claim that traditional application software can benefit from incorporating fun, in terms of both learnability and user engagement. As Carroll (2004) points out, "people must want to use a system, and must continue wanting to use the system" and fun, he continues, may provide an answer to this challenge. The author further comments that usability, if understood as simplicity and ease of use, is not the only relevant aspect for the success and adoption of application software; correspondingly, he recommends towards an expanded notion of usability that will include fun and other aspects of the user experience. Similar shifts from standard usability to issues of fun, enjoyment and the user experience have been articulated within the 'funology' movement, an initiative in the early 2000s (Monk et al., 2002; Blythe et al., 2004). Furthermore, studies on pleasurable products as well as studies on the impact of aesthetics on the interaction have also contributed to this shift. Today, user experience research is a prominent subject within HCI. As summarized by Hassenzahl and Tractinsky (2006), current user experience research is engaging with non-instrumental human needs, the role of affect and emotions in the interaction and the nature of experience. Not surprisingly, the authors conclude with a vision of HCI as being able to "contribute to our quality of life by designing for pleasure rather than for absence of pain", the latter being often understood as the predominant contribution of standard usability.

The understanding, promotion and evaluation of the fun component in the interaction is, by now, a relevant topic of HCI research, but what is actually fun in HCI terms? For Draper (1999) fun is "playing for pleasure" and a form of intrinsic motivation. Carroll (2004) finds fun in things that "attract, capture, and hold our attention by provoking new or unusual perceptions, arousing emotions in contexts that typically arouse none, or arousing emotions not typically aroused in a given context". The author also considers a play component when assigning fun to things that "present challenges or puzzles to us as we try to make sense and construct interpretations". Shneiderman (2004) talks about "fun-filled experiences" as "playful and liberating" and distinguishes between fun-in-doing and fun-in-not-doing. Marcus (2007) associates fun in the user experience with play, games and humour but is careful to remind us that fun is a complex cognitive and emotional issue. Taking a more experiential approach, Blythe and Hassenzahl (2004) distinguish between fun as distraction and pleasure as absorption, the latter being closely related to the concept of flow. At the end, what all scholars

seem to share is the belief that we can achieve a feeling of euphoria during or via an interaction, be it fun, enjoyment or pleasure. However, the means to reach such a state are various and will vary across tasks, environments and people.

It should be clear that there are no recipes for enjoyable interfaces. It is worth examining, though, the suggestions and guidelines that have been articulated so far. Shneiderman (2004) requires that fun interfaces respect the task at hand and safeguard usability and reliability before they are spiced up with fun features. His toolkit of fun features consists of graphics, animations, sounds, alluring metaphors and compelling content. In our view, the toolkit is strongly oriented to enhancing the aesthetic appeal of the user interface component of an application. While this is a valid strategy, we ponder about the possibility to evoke enjoyment by devising activities that are actually fun in themselves. To paraphrase Overbeeke et al. (2004), "emphasis should shift from a beautiful appearance to beautiful interaction, to engaging interaction. And this should not be a glued on quality": Replacing 'fun' or 'playfulness' in place of 'beauty' should clarify our point. Other guidelines draw inspiration from play and playfulness. Malone (1982), in a classical work, proposes heuristics for the design of enjoyable interfaces by examining how players of video games experience fun. His heuristics, namely challenge, fantasy and curiosity, were originally conceived for the analysis of instructional environments, and as such, they predominantly focus on stimulating motivation. Graphics or sounds are considered only as stimulating to curiosity and less as elements of an aesthetic experience. Kuts (2009), in her examination of playful interfaces, reports on aspects of the interface that are considered playful, such as exploration, customization and feedback, and proposes a set of user interface components to promote them. Eventually, her proposal suffers from the same 'spicing up' strategy. Finally, Kim (2008) proposes designing fun application software by incorporating common video game mechanics, such as collecting, earning points, receiving feedback, exchanging and customizing. The speaker's ideas are representative of a now blooming trend in interaction design, i.e. the gamification of application software, which will be discussed in depth in the next sub-section.

Finally, a word of mention is due to the notion of 'ludic interfaces' as envisioned by Gaver (2002). The author borrows the term 'ludic' (as in Huizinga's 'homo ludens') to raise a case for interfaces that are playful as in being ambiguous and open to interpretation and appropriation. The author views playfulness as curiosity and exploration, clearly opposes game and play, the latter being free and unbound to rules, and advocates the need to engage with technology and technological artefacts in ways that are open-ended, interpretative and non-task

oriented. His suggestion is that similar principles should propagate into our methodologies for designing artefacts and interfaces. The notion of 'ludic interfaces' may be truer to the needs of a 'playing man' than any other notion of play-full and game-full (cf. gamification) interaction within HCI. It may also be truer to the needs of a 'playing researcher', i.e. of both the target user group of this thesis as well as myself.

HCI and games: A marriage of convenience

The work of Malone (1982) was one of the early encounters between HCI and video games. In the meantime, the video game market has expanded significantly and interest in video games has increased enormously. HCI is yet another discipline flirting with video games but, as Jørgensen (2004) observes, the exchange between HCI and games can be bidirectional.

Video games are pieces of software that perfectly qualify as a study subject for the field of HCI. Traditional HCI methodologies, such as usability evaluation and user testing, can be directly beneficial for the development of video games. Numerous examples are provided in Jørgensen (2004); Barr et al. (2007) and Zaphiris and Ang (2007). Moreover, as Barr et al. (2007) advocate, methods that are specific to video games need to be devised. On the whole, HCI research can deliver considerable contributions to the field of video games. On the other hand, given the success and popularity of video games, HCI is attentive for ideas and opportunities that may inform the design of traditional application interfaces. The idea that good video games can teach us how to make good interfaces is not new: Malone (1982) proposed his heuristics for the design of enjoyable interfaces as early as 1982. Links between HCI and games were put forward for discussion in conference workshops in 1994 (Pausch et al., 1994) and 1997 (Cherny et al., 1997). More recently, Dyck et al. (2003) derived aspects of game interfaces that can be relevant for the design of traditional interfaces. On a side note, their work is notable for it examines potentially useful interaction techniques rather than ways to stimulate fun and enjoyment. More encounters between HCI research and games have sprung: A delightful historic overview is provided by Turner and Browning (2010). As most of our bibliography tagged by [hci][games] features in this report, we will refrain from repeating the same timeline here. Still, we wish to set this tradition against a few recent developments in the quest for enjoyment and engagement by means of gaming or game elements, namely gamification, serious gaming and games with a purpose.

Gamification: Gamification as "the use of game design elements in non-game contexts" (Deterding et al., 2011) is a relatively new development in the design of application software. While a new kid in town, the idea may be not much different from previous attempts to learn from existing knowledge and practices from video games in order to increase user engagement. Deterding et al. (2011) acknowledge that gamification nears the tradition of 'playful interfaces' but they are confident that gamification can serve as a research topic of its own sake. The trend has already been heavily criticized by game scholars and game designers alike, who observe a tendency to superficially gamify applications. Much too often, application designers have advocated gamification of applications by means of extrinsic rewards resulting in an abuse of game elements such as points and badges. At present, the HCI community remains active in discussing and better understanding the issues around gamification, especially the issue of motivation via game elements.

In principle, neither gamified applications nor playful/enjoyable interfaces (cf. subsection 1.4.2) are actually games. A significant exception is the work of Chao (2001), who created a pure first-person shooter for the administration of computer processes. The author relates to the term game-like interface, a notion we endorse and comment upon in chapter 3. But actual, full-scale games have also been appropriated within HCI:

Serious games: Serious games are games for purposes other than mere entertainment (Susi et al., 2007; Alvarez and Michaud, 2008). The underlying idea is that educational or other objectives can be successfully conveyed via the medium of video games. Serious games have found applications in a variety of fields and industries such as education, marketing, training and social awareness but their success and quality varies. For example, instruction games with drill and practice exercises have been heavily criticized as 'the worst of two world', i.e. bad education and bad gameplay (Charsky, 2010). On the contrary, simulations and games that train the corresponding skills, be it motor skills or problem solving skills, may have more promising potential.

Games with a purpose: Games with a purpose (von Ahn, 2006) are games that harvest human effort during play. As such, they provide an effective mechanism to utilize humans for traditionally challenging areas of computation. The underlying idea is that we can engage humans in tedious tasks, and bring human computation and crowd-sourcing to a new level, if we transform these tasks into

games. The paradigm has been applied successfully at numerous occasions for problems that are either computationally challenging or simply tedious. For example, the 'ESP game' (von Ahn and Dabbish, 2004) was a pioneering example in producing semantic image annotations, i.e. annotations about the content of an image, via game play. Siorpaes and Hepp (2008) review more game examples relevant to the field of semantic web technologies, an area that traditionally requires painstaking effort in capturing human knowledge. Another significant example of human computation via play can be found in the domain of biological sciences. The game 'fold-it' is a puzzle game for predicting protein structures. Players of the game have collectively outperformed state-of-the art algorithms while, at the same time, suggesting new solution strategies (Cooper et al., 2010).

All of the above developments share an interest in tapping the popularity and success of video games. Games work, at least well-designed ones do, so, naturally, many disciplines consider the applicability of gaming for their own purposes, be it learning, computation, engagement or improved user experience. We are confident that engaging instances of playful work and of useful play, of games that 'do more' and of applications that are more playful can be delivered. We acknowledge that ideas from gaming can be useful and applicable to a variety of domains often irrelevant to gaming itself and that application interfaces can benefit from the positive effect of fun and play. Then again, our outputs are not *per se* serious games nor applications gamified. First and utmost, our outputs are platforms to actively engage with and contemplate about scientific images. Hopefully, we have explored a tiny bit of that "vast and utterly neglected territory of possible systems that are really neither work nor fun" (Sengers, 2004).

1.5 Structure of the thesis

The coming chapters document our attempts to better understand how play for exploration could be catered for. Via case studies and reviews, we flesh out particular elements of play for exploration and implement artefacts that exemplify instances of playful interaction with image research material in collections.

Chapter 2 introduces the CSIDx database system (Cyttron Scientific Image Database for eXchange). The system and its data management approach, in particular the extensive use of ontology annotations, are discussed in depth. An understanding of the scope and intentions of the CSIDx system should further illuminate some of the requirements put forth in this introduction. Connectivity across microscopy techniques, users and subject matters is one of the founda-

tion stones of the Cyttron project; as such, the context provided by Cyttron has strengthened our interest in connections and associations. With respect to the notion of playful exploration, we discuss information visualization features of the CSIDx web interface that are supportive for exploration.

Chapter 3 presents Onto-Frogger, a video game prototype developed for the CSIDx image database. In chapter 3, we elaborate on the use of gaming for exploration: Onto-Frogger implements a form of playing with images that is clear-cut gaming. What is more, we introduce a new concept, that of games as 'executable' information visualizations, and suggest that games may materialize structure and existing connections when encoding them in their game logic. Our produced game is heavily oriented towards images, their annotations and the connections implied by these annotations. Onto-Frogger implements a way to literally play with images that exposes the users/players to the underlying structure of the data collection by challenging them to identify, predict and resolve existing connections for the needs of the game.

Chapter 4 takes a step away from the CSIDx database to question what lessons can be learned from existing practices in popular image collections and from existing games involving digital images. In chapter 4, we review image-based gaming activity as exercised in the Flickr photo sharing system. The work presented contributes a first scouting of the Flickr ecosystem and a first categorization of the gaming activity present. But mostly, it contemplates on the exploratory qualities of the found activity to derive potentially promising ideas to further support playful and exploratory interactions with images in collections.

Chapter 5 presents LABBOOK, a collaborative storytelling game for biologists and their images. In chapter 5, we investigate storytelling as a form of playing with images. In effect, and in response to our findings in chapter 4, we divert from rule-based play in favour of play that is more creative and more unstructured. The work presented in this chapter attempts to probe creative responses to images by confronting the players with the challenges of story composition. LABBOOK implements a way to literally play with images that challenges the users/players to imagine connections and devise explanations for the needs of the game. The game is also an invitation for social exchange and conversation.

Chapter 6 concludes this trip.

Chapter 2

The Cyttron Scientific Image Database for eXchange

Based on:

A. Kallergi, Y. Bei, P. Kok, J. Dijkstra, J. P. Abrahams, and F. J. Verbeek. Cyttron: A virtualized microscope supporting image integration and knowledge discovery. In C. Backendorf, M. Noteborn, and M. Tavassoli, editors, Proteins killing tumour cells, Cell Death and Disease Series, pages 291–315. ResearchSignPost, 2009a

A. Kallergi, Y. Bei, and F. J. Verbeek. The ontology viewer: Facilitating image annotation with ontology terms in the CSIDx imaging database. In Workshop on Visual Interfaces to the Social and the Semantic Web (VISSW2009), February 2009b

Abstract: This chapter introduces the Cyttron Scientific Image Database for eXchange (CSIDx), a multi-modal imaging database for images produced in the life sciences. The database was developed within the framework of the Cyttron project, a consortium intended to create an integrated infrastructure for bio-imaging. As the CSIDx database and community provide the use case of this thesis, the aims of both the Cyttron and the CSIDx initiatives are relevant. Moreover, some familiarity with the data involved in this thesis and their organization in the repository should be beneficial for the reader. Of particular interest is the extensive use of ontology annotations for the management of image data: Semantic annotation is proposed as a requirement for the management, sharing and integration of images. Ultimately, and with respect to the notion of playful interaction, we elaborate on information visualization features introduced in the CSIDx interface in order to better exemplify the CSIDx data and collection.

2.1 Introduction

"An image is worth a thousand words". Surely, but does this conventional wisdom apply to scientific images produced in the life science as well? In one hand, we need to consider whether biological images are straightforward enough to speak for themselves. On the other hand, we need to consider if a single image is enough to tell the whole story. And finally, we need to ask ourselves what the point of a thousand words is, if none is listening anyway. The answers to these seemingly innocent questions have implications on how we envision and design digital systems for the management of scientific image data in biology and the life sciences.

Imaging is an indispensable practice for biological research. With researchers producing proliferating numbers of image data, data management soon becomes an issue. What is more, there is a wealth of image research material that could benefit other researchers but is never shared. Assuming that image provenance is well-tended, the benefits from sharing one another's "treasure chests of images" (Marx, 2002) should be self-explanatory. That said, delivering systems to support image-based biological research, systems that will better the management, sharing, remote access, interoperability and integration of image data, as advocated by Swedlow et al. (2009), is not without its challenges. Consider, for example, the content of biological images: The subject depicted is rarely evident and may depend on the experiment design (e.g. which gene is being tagged). To quote Goldberg et al. (2005), "deriving information from images is completely dependent on contextual information that may vary from experiment to experiment". A system or repository will need to assure sufficient metadata, i.e. data about the data, for the stored images to be of any use. Furthermore, well-described content is not sufficient without utility. The system will need to provide useful services and user-friendly interfaces for the researcher to benefit from the maintained images. To put it differently, we need good data to be put in good use by both machines and humans; the latter, we argue, can be empowered by means of an interface. Well-designed interfaces, effective displays and interactive tools can empower the human researcher by both easing her tasks and amplifying her cognitive capacities. During the development of the CSIDx image database, we soon realized that, one, an image can not "speak for itself" and, two, we need to pay attention to a neglected aspect of scientific management systems, i.e. the user interface.

Image-based biological research is often multi-modal, i.e. involving various imaging modalities. The study of a biological phenomenon frequently requires combining observations of various levels of abstraction and such observations

will be recorded by instruments operating at various levels of resolution. Multimodal imaging is typically performed on the same biological sample using imaging instruments that support multiple imaging techniques (Bonnet, 2004). Other comparative microscopic studies such as imaging in both 2D and 3D dimensions, i.e. multi-dimensional imaging (Bonnet, 2004), are also frequent. Eventually and to fully comprehend a biological phenomenon, we need contributions from various domains of biology, operating at the organism/cell/protein/molecular level; such contributions may not always be derived from the same sample. Consider as an illustration the concept of apoptosis, i.e. programmed cell death. The phenomenon can be studied at the cell level, by examining the phenotype of an apoptotic cell, at the protein level, by locating proteins responsible for apoptosis and at the molecular level, by identifying the structure of the proteins involved. The imaging techniques employed could be light microscopy, electron microscopy and crystallography respectively. In short, a single image/imaging technique is not always enough to tell the whole story: Biological research needs an integration of observations/images from the cellular level down to the molecular level. This realization lies at the heart of the Cyttron project, the host project underlying the development of the CSIDx database.

The structure of this chapter is as follows: Sessions 2.2 and 2.3 present the aims of the Cyttron and CSIDx initiatives respectively, and summarize their visions about biological research practice, data management and data integration. The Cyttron context and the nature of the CSIDx data have impregnated our understanding of what useful interactions with images may be. Section 2.4 describes in depth the CSIDx system and web interface, paying particular attention to the process of image annotation. Having established our context and background, we shift our attention to the capacities of the interface as a means to better understand and further explore the CSIDx data. In particular, section 2.5 elaborates on information visualization principles introduced in CSIDx in order to improve on some of the user tasks and foster a better understanding of the CSIDx data and collection.

2.2 Aims and scope of the Cyttron project

The Cyttron consortium was a publicly funded project initialized in 2004. The project brought together a consortium of academic and industrial partners with the goal to implement an integrated infrastructure for bio-imaging. Such infrastructure could facilitate biological research by providing a generic platform for studying and modelling biological phenomena over various resolutions, i.e. from

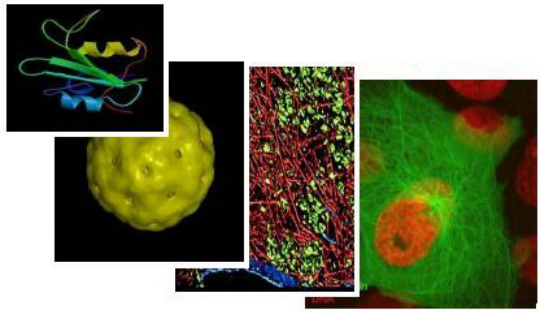


Figure 2.1: The Cyttron visual rhetoric: 'Zooming in' the cell. From right to left, a cell with a tagged protein, the ultrastructure of a cell, a virus molecule and a protein. Implied in the visual is the ability to move across imaging modalities, from the micro scale down to the atomic level.

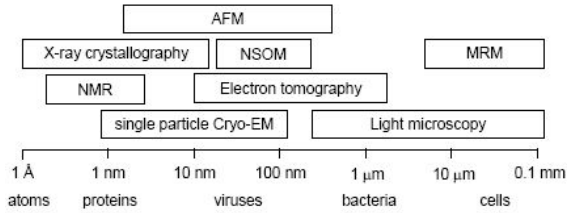


Figure 2.2: Overview of imaging modalities addressed in the Cyttron platform. Each modality is represented by a rectangle with its specific range of resolution and overlap with other modalities.

the cell level down to the molecular level. As said, implicit in the project is the realization that the study of a biological phenomenon often spans across multiple imaging techniques. Table 2.1 summarizes some of the modalities that were deemed relevant for the Cyttron platform based on their relevance for contemporary life science practice. From the perspective of the user, an integration of images depicting a phenomenon at different levels of detail is highly desirable. During Cyttron meetings and symposia, the metaphor of a virtualized microscope that would allow 'zooming in' at various resolution levels was developed. Figure 2.1 became iconic of the aims of the project.

Being an interdisciplinary consortium, the Cyttron project addressed the challenge of image integration from a multiplicity of approaches. As shown in Figure 2.2, imaging modalities often overlap in resolving power. By means of image registration, this overlap in resolution can be exploited to establish connections between images of the same sample. A significant part of the Cyttron project engaged in bettering the overlap between microscopy techniques by extending the resolution, range or throughput of existing technologies. This approach was particularly prominent in partners involved with hardware and/or imaging protocols.

Another approach, shared by the software groups of the project, focused on the development of a common software platform that would provide seamless and continuous access to diverse image data. The notion of a common platform was conceived at both the visualization level (images should be visualized in the same viewer) and the data model level (data about the images should comply to the same data model). As a result, the common visualization platform was implemented as two distinct but complimentary and co-operating software products, namely the CVP (Common Visualization Platform) viewer and the CSIDx image database. In effect, the integration of images was attempted at both the pixel and the metadata level.

2.3 Aims and scope of the CSIDx system

The Cyttron Scientific Image Database for Exchange (CSIDx) is a multi-modal imaging database for images produced in the life sciences. CSIDx was built to be the backbone repository of the Cyttron project; as such, CSIDx was designed to support a wide range of imaging modalities and techniques, as well as a variety of users and research practices. With respect to the aims of Cyttron, CSIDx proposes an integration of images based on their metadata and semantic content. Multi-modality and semantic image annotation are the two core requirements for CSIDx.

CSIDx was also designed to be a web-based resource and community for researchers from various institutes to share image resources. It is highly unlikely that the same scientist or research group can produce data across the full range of existing modalities. Therefore, a seamless integration across the resolution range is only possible via principles of sharing and collaboration. CSIDx is a manifestation of a community of scientists wanting to learn from connections established across one another's images.

2.3.1 Multi-modality

From the impressive number of databases publishing data from the life sciences[1], only a small portion provide microscopy images. Table 2.2 enlists several examples of biological image database systems; the list is not exhaustive but is a compilation of systems and repositories discussed by Walter et al. (2010); Linkert et al. (2010); Swedlow et al. (2009); Lindek et al. (2006). Genomics databases

[1] Consider as an illustration the 'Nucleic Acids Research' inventory of molecular biology databases containing 1330 resources (Galperin and Cochrane, 2011).

Table 2.1: Some of the imaging modalities addressed in the Cyttron platform.

Modality	Description	Level of Resolution
Magnetic Resonance Microscopy (MRM)	Can potentially visualize the interior of a cell inside an organism, permitting *in vivo* imaging.	small organisms, organs, cells (up to 10 μm)
Light Microscopy	Can visualize live cells and can trace the movements of single molecules through a cell, provided that they carry a fluorescent label. Three- and four dimensional imaging allows capturing dynamic information.	tissues, cells (typically around 1 to 10 μm)
Electron Tomography	Allows visualization of cellular ultrastructure in 3D. Cells need to be fixed, so dynamic information must be obtained via comparative studies.	cells, organelles/subcellular structures (typically around 0.5 to 10 nm)
Atomic (Scanning) Force Microscopy (AFM)	Can visualize non-crystalline proteins and protein complexes. It can potentially image cellular surfaces and may be used to visualize live cells.	subcellular structures, bacteria, ribosomes, protein complexes (up to 1nm)
Single particle cryo-EM	Can visualize very large bio-molecular complexes, not necessarily crystalline or purified. Samples are frozen at (at least) liquid nitrogen temperatures, therefore dynamic information cannot be obtained from single molecules but must be inferred via comparative studies.	proteins (up to 1 nm)
Nuclear Magnetic Resonance (NMR)	Can visualize non-crystalline proteins, in purified form and labelled with stable isotopes with a limited size range. Provides dynamic information about the mobility of the protein and interactions between proteins.	membranes, proteins, atoms
X-ray crystallography	Can determine atomic structure but the sample must be crystalline, and so the throughput of the technique is limited.	proteins, atoms (up to 1 Å)

often provide fluorescence images to verify or illustrate gene expression data, while proteomics databases frequently provide visualizations, i.e. models of protein structure, to render their content. In both cases, however, one can argue that the unit exchanged, i.e. stored, annotated, queried and retrieved, is the genomics or proteomics data rather than the microscopy images or models. Resources dedicated to model organisms also provide microscopy images on the anatomy, phenotype and gene expression of the organism under study. Finally, when microscopy images are the focus of the repository, the system is often originally oriented towards a particular imaging technique or a particular field of biological research. CCDB (cf. Table 2.2) was initially designed for electron microscopy data but is now expanded to various light microscopy techniques. A couple of projects, namely Bioimage and SIDB (cf. Table 2.2), were originally designed to host images from various modalities. Table 2.2 also includes two significant software initiatives, namely OME and Bisque, that do not host research data but deliver open source platforms for image management.

Obviously, the design requirements of CSIDx dictate that a wide range of imaging techniques is supported. Supporting a multiplicity of imaging techniques is a challenge that manifests at various levels. On the file format level, the system needs to cater for a variety of image formats with often proprietary characteristics. Regarding the data model, some flexibility in metadata must be afforded as microscopy techniques vary considerably in their material and methods. Finally, the interaction design needs to accommodate users with diverse methodologies, workflows and requirements.

2.3.2 Semantic image annotation

In the core of CSIDx is the need for an extensive annotation of the image data. Thorough and unambiguous annotation is proposed as both the means to link modalities and a necessary requirement for image sharing and reuse. It should be repeated here that the content of biological images is rarely self-explanatory but must be supplied by the image producer or by researchers in the corresponding research field; lack of metadata will simply result in meaningless and unusable data. Linking images will also require metadata. To begin with, linking images by exploiting the resolution overlap between modalities will require metadata about the production of an image. Depending on the image format, microscopy settings may be available as header information but information about the experiment design, e.g. sample preparation, must be provided by the producer of the image. Most importantly, CSIDx proposes an integration of images via biological

Table 2.2: Selected list of image databases developed for the life sciences as compiled from Walter et al. (2010); Linkert et al. (2010); Swedlow et al. (2009); Lindek et al. (2006).

Name	URL	Short Description	Status
BDGP insitu	http://insitu.fruitfly.org	Patterns of gene expression in Drosophila embryogenesis, generated by high-throughput RNA in situ hybridization.	Active
4dxpress	http://ani.embl.de/4DXpress	Gene expression data acquired through whole mount in situ hybridisation.	Active
EMDatabank	http://emdatabank.org/	Global deposition and retrieval network for cryoEM map, model and associated metadata.	Active
Allen Brain Atlas	http://www.brain-map.org	Gene expression and neuroanatomical data.	Active
The e-Mouse Atlas Project	http://www.emouseatlas.org	EMA provides histology sections and 3D reconstructions of mouse embryos, EMAP provides gene expressions generated by various in situ assays.	Active
Flybase	http://flybase.org	Genetic and genomic data on Drosophila melanogaster and the insect family Drosophilidae, provides graphics and microscopy images to illustrate anatomy and development.	Active
zfin	http://zfin.org	Zebrafish genetic, genomic, phenotypic and developmental data, compiles images of anatomical structures, phenotype images and gene expressions from various assays.	Active
Protein Subcellular Location Image Database (PSLID)	http://murphylab.web.cmu.edu/services/PSLID	2D to 5D fluorescence microscopy images depicting subcellular location proteins, focus is on image processing.	Unspecified
Mitocheck	http://www.mitocheck.org	Regulation of mitosis by phosphorylation, high-throughput live cell imaging of a genome-wide RNA interference (RNAi) screen, focus is on image processing.	Ended
The Cell Centered Database (CCDB)	http://ccdb.ucsd.edu	2D, 3D and 4D data from light and electron microscopy, including correlated imaging.	Active
Bioimage	-	Multidimensional microscopic images of biological samples, broad scope.	Ended, offline
Scientific Image DataBase (SIDB)	http://sidb.sourceforge.net	2D, 3D images, time series, broad scope.	Ended
JCB data viewer	http://jcb-dataviewer.rupress.org	Visualization tool for original image data files associated with JCB (Journal of Cell Biology) articles, various image formats, mostly light microscopy, but also autoradiographs, (scans of) immunoblots, and histology and electron micrographs.	Active
Bisque	http://www.bioimage.ucsb.edu/bisque	Open source platform for data management in the life sciences.	Active
Open Microscopy Environment (OME)	http://www.openmicroscopy.org	Open source platform for data management in the life sciences.	Active

concepts, i.e. based on the phenomenon or sample under study. To that end, consistent and accurate metadata on the content of an image is essential.

To capture the content and interpretation of an image, CSIDx utilizes ontology terms from numerous ontologies relevant to the domain of the life sciences. Ontologies are formal specifications of a domain, modelling the domain concepts and relations, and have description logic underpinnings. For our present discussion, it suffices to describe ontologies as collections of concepts and their relations. Used for annotation instead of user generated keywords or tags, ontologies provide a consistent and unambiguous vocabulary across images, modalities and researchers. Domain specific, curated ontologies capture the nomenclature of the particular field. Finally, the relations between concepts can be further exploited to organize and link the annotated image data. The initiators of CSIDx envisioned a semantically enhanced integration of images achieved by reasoning over the ontologies. As a matter of fact, one of the solutions envisioned would output a graph of images that are linked together not only explicitly, based on the assigned metadata, but also implicitly, based on derived relationships (Bei et al., 2007).

2.4 The CSIDx system

The CSIDx system consists of a relational database management system to store images and their metadata, a relational database management system to store ontologies and a web interface for registered users to access and manage their images. The system is developed, maintained and hosted by the Imaging and Bioinformatics group in Leiden University.

2.4.1 Data management in CSIDx

An image entry in CSIDx is a composite entity of both raw pixel data and user generated metadata (annotations). Bei et al. (2006) put forth the requirements for a sufficient annotation that respects the particularities of scientific image production. It is useful to repeat here that, as regards biological image data, a sufficient annotation should record the following aspects of an imaging experiment:

- *Who* did the experiment, including information about the image owner and the research facility the image was produced in.
- *What* the experiment is about, including information about the biological phenomenon the image depicts or attempts to study.
- *How* the experiment was done, including information about the instruments utilized and the experiment design.

In response, CSIDx stores the following categories of metadata:

- Administrative metadata, capturing information about the owner of the image and the access rights to an image entry (the *who*). Users are organized under research groups and access to resources can be granted group-wide or community-wide.
- Ontology metadata, capturing information about the content of an image entry (the *what*). To safeguard accuracy, ontology metadata are expressed in ontology terms derived from life science related ontologies. The system incorporates 37 ontologies, the majority of which were retrieved from the Open Biomedical Ontologies (OBO) Foundry (Smith et al., 2007).
- Microscope metadata, capturing information about the experiment setup (the *how*). To maximize flexibility, microscope metadata are stored as pairs of settings-values. Generic microscope templates, i.e. lists of representative fields for an instrument or imaging technique, are provided to guide the annotation. For example, the confocal microscope template includes fields such as laser line, laser type, emission wavelength, objective lens and others. Groups can create their own group-specific microscope templates to be used instead of or in conjunction with the generic templates.
- Image metadata, capturing basic features of the image file e.g. file size. Such metadata are usually extracted automatically.
- External links, maintaining links to existing pieces of knowledge in external resources[2].

An entry from the CSIDx database, illustrating the various metadata stored together with the raw pixel data, can be seen in Figure 2.3. As thoroughly explained in subsection 2.3.2, semantic annotation by ontology terms derived from life science related ontologies lies at the core of CSIDx and our data management approach.

2.4.2 The CSIDx web interface

The CSIDx web interface allows registered users to access and manage their images. The interface supports annotation of one's own images, administration of resources, such as terms and templates, and search and retrieval of all visible images. Kallergi et al. (2009a) provide an extensive description of the CSIDx web interface; this subsection will only briefly discuss the nuts and bolts of the CSIDx web interface regarding the image annotation process.

[2]While not part of the initial specification by Bei et al. (2006), external links were suggested by subsequent user studies.

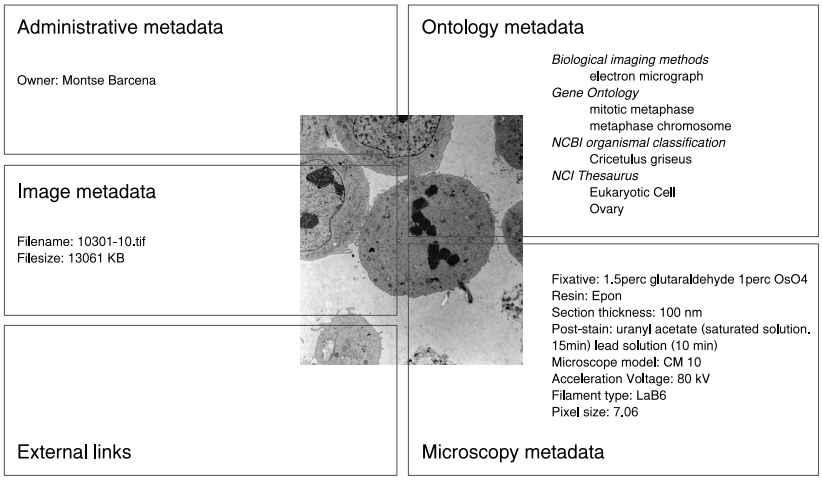


Figure 2.3: Image entry in CSIDx. Image entries in CSIDx are composite entities of both raw pixel data and user generated metadata (annotations). Image courtesy of M. Barcena, Department of Molecular Cell Biology (MCB), section Electron Microscopy, Leiden University Medical Center (LUMC).

Image annotation is a central task in CSIDx. An overview of tasks involved in the workflow of image annotation is given in Figure 2.4. In a simple use case scenario, the user uploads her images and annotates them with ontology terms she collected beforehand ('My terms') and with (generic and/or specific) microscope templates. Some of the graphical user interface (GUI) elements used during an annotation are illustrated in Figure 2.5. Generic microscope templates are curated centrally while group specific microscope templates are to be maintained by the group administrator; both types of microscope templates should be readily available to the user during annotation. Annotation by ontology terms utilizes terms out of a subset of terms the researcher has compiled beforehand ('My terms'); once such as set is compiled, it is available to the user for all subsequent annotation sessions.

Thorough image annotation by a human expert is a time-consuming and demanding task. In order to reduce overhead, the CSIDx interface provides additional options such as the possibility to annotate similar images simultaneously and the possibility to store an annotation into an annotation template to be applied on subsequent images (cf. Figure 2.4). Specific to the annotation with ontology terms is the above-mentioned strategy of 'My terms', i.e. the preselected collection of terms that are of interest to the researcher. Introducing ontologies for annotation was not without its challenges for our users and coping with the vast amount of available terms was one of them (Kallergi et al., 2009b). The strategy of 'My

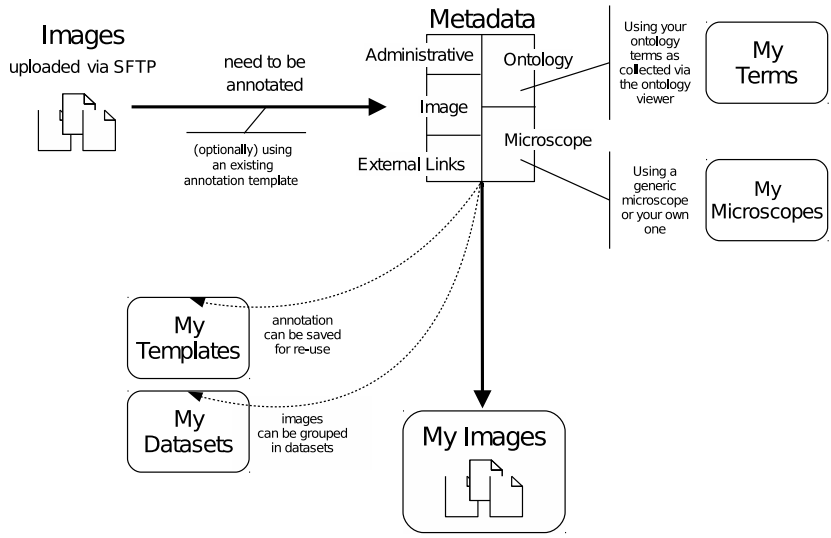


Figure 2.4: Overview of the tasks involved in image annotation.

terms' requires a preparation step but, in effect, minimizes the effort of searching and identifying relevant terms (search once, use in all subsequent annotations). It also reduces the overwhelming amount of ontology terms to a meaningful and manageable subset. Collected ontology terms can be shared among members of a group who are likely to engage with the same research subject. On the whole, effort has been expended that a proper annotation is reused whenever possible.

It should be remarked that the development of the CSIDx interface has been a dynamic and evolutionary process. New features were implemented in collaboration with users and via case studies on biological topics suggested by the Cyttron community. For obvious reasons, a major part of our development effort was dedicated to improving the process of image annotation. We are thus particularly aware of the challenge of acquiring quality metadata in a user-friendly way. That said, the remainder of this thesis will, for the most part, consider semantically annotated images as a given. In a sense, we will shift attention from data acquisition to data access and 'consumption'.

2.5 Visualization for interaction

As the backbone repository of Cyttron, CSIDx is also meant to provide data access to various software clients. For example, the CVP viewer retrieves data and metadata from CSIDx to be further visualized in a dedicated visualization environment.

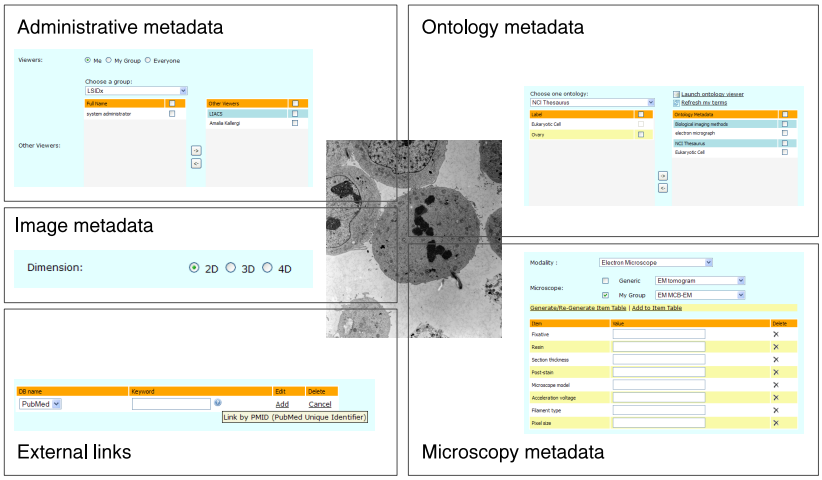


Figure 2.5: Various GUI elements used in the CSIDx web interface for submitting the various types of metadata during an annotation. Image courtesy of M. Barcena, Department of Molecular Cell Biology (MCB), section Electron Microscopy, Leiden University Medical Center (LUMC).

Potentially useful algorithms or services, e.g. image convulsion, feature extraction etc., could be executed on the available data. Seen from this perspective, the web interface is yet another client using the CSIDx database and one that ensures that well-annotated data are available for other services.

Of course, there is more to be supported in an interface than only populating the database. Effective displays and interactive tools can engage the human researcher in examining and exploring the available data. The remainder of this thesis investigates these ideas in depth but efforts to support exploration have already been attempted within the web interface. More specifically, we consider and apply ideas from the field of information visualization to better exemplify our metadata or to provide an overview of the collection. Information visualization is a well-established field exploiting the visual capacities of humans in order to reinforce understanding of data. Note that in this context, visualization refers to the visualization of the metadata of the images and not of the raw data.

2.5.1 Visualization of ontologies

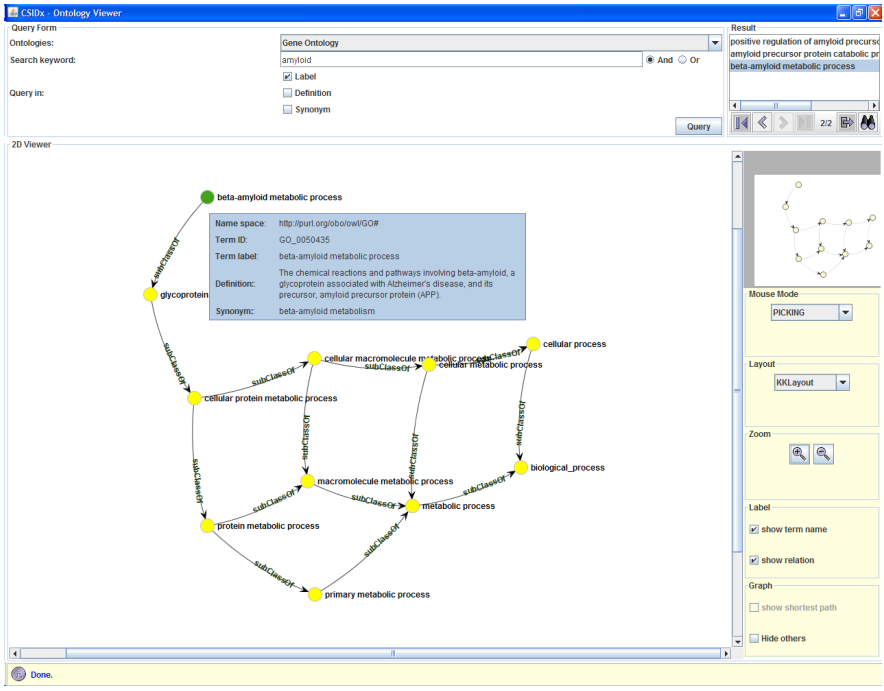
Visualization of ontologies was introduced in the CSIDx system as a means to assist the process of image annotation with ontology terms. While part of the annotation process, the graphical tool implemented is worth mentioning for it provides a visual aid on a core aspect of CSIDx, i.e. the ontology metadata. Noticeably, introducing ontologies for image annotation was a considerable challenge

for our users who were hindered from unfamiliarity with ontologies and from the overwhelming amount of ontology terms. Kallergi et al. (2009b) fully document the difficulties observed and the actions taken in response. Here, we focus our discussion on the employment of a graph visualization to better exemplify ontology metadata.

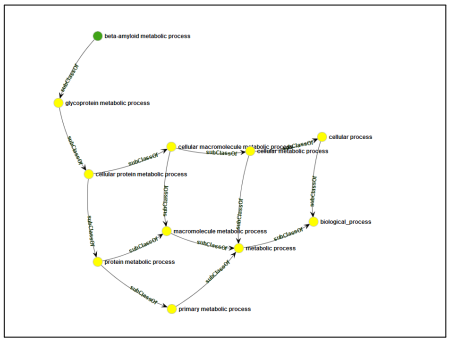
The ontology viewer (cf. Figure 2.6) is a web application that accesses the ontology database of the CSIDx system. It consists of a query form for querying ontology terms and a 2D viewer for visualizing ontology structure. In the 2D viewer, the ontology structure is shown as a graph: Terms are graph nodes and relations are graph edges. Selected ontology terms, as collected from a query, are used to extract a sub-graph of the ontology graph. This sub-graph provides the local context for the selected nodes which are highlighted green to distinguish from their connected terms. A short description with information on any given term can be obtained by hovering over the corresponding graph node. Regular graphical manipulations are supported and the ontology graph can be zoomed, panned, rotated and sheared. For optimal spatial arrangement, the user can switch between a number of different graph layouts. The graph drawing and manipulation was implemented by means of the Java Universal Network/Graph (JUNG) framework (O'Madadhain et al., 2005). The ontology viewer is developed as a Java Web Start application and is available to registered users of the CSIDx database.

For most CSIDx users, the ontology viewer was their first impression on biological ontologies. As such, the ontology viewer functions as an introductory tool for users to familiarizing themselves with the concept, structure and content of ontologies. The tool was reported to improve the mapping of expert knowledge to ontology terms by eliminating ambiguities and by enriching the vocabulary of the user. What is more, the ontology viewer made the concept of ontologies and of semantic annotation concrete and explicit to our users. The graph representation, although an over-simplification from a formalist's perspective, sufficiently communicated the added value of ontologies, i.e. semantic relations. In a sense, and by making the connection between concepts explicit by visualization, the vision of CSIDx as a semantically rich repository was better comprehended and valued.

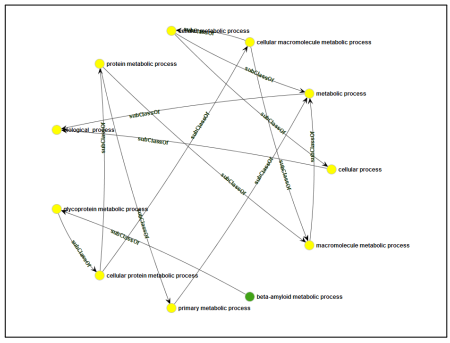
As users familiarize themselves with the ontology structure, they express the wish to further interact with the ontology graph. Compared to a full-scale visualization tool, the ontology viewer will be found lacking in functionality; after all, the tool was initially conceived to provide some context for the queried ontology terms. Nonetheless, the educational potential of the tool is of considerable interest. Our



(a) The ontology viewer interface



(b) KKLayout



(c) CircleLayout

Figure 2.6: The ontology viewer. The query form (Figure 2.6a, top panel) is used to search for ontology terms which can be then visualized in the 2D viewer. Here the subgraph of 'beta-amyloid metabolic process' (Gene Ontology). Figures 2.6b, 2.6c show two different renderings of the same subgraph in the KKLayout and CircleLayout respectively.

research group has continued investigation on ontology visualization resulting in full-featured visualization tools for ontologies (Dmitrieva, 2011).

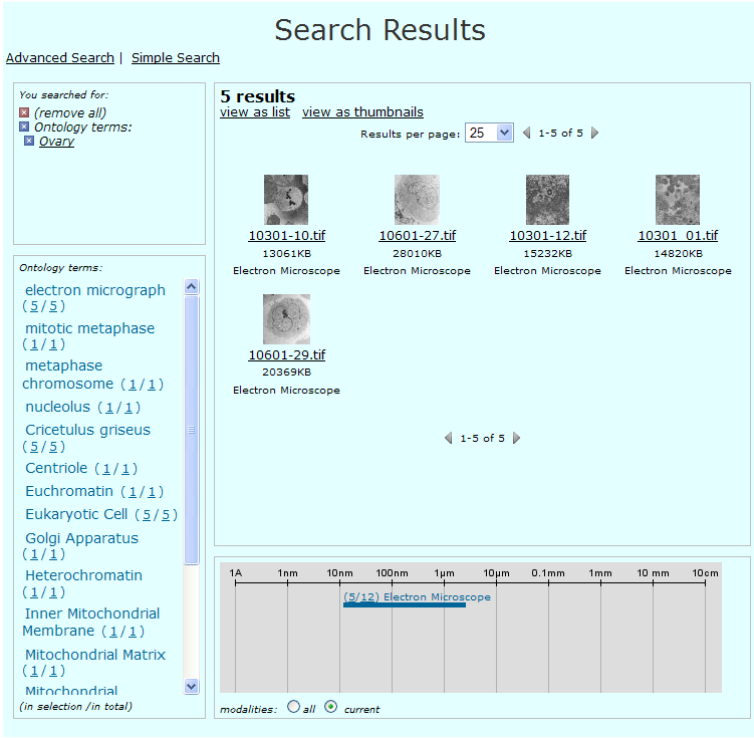
2.5.2 Visualization of search results

From plain lists of hits to more elaborate visualizations, the presentation of search results is a central component of any search interface to a data repository. By means of visual encodings, visualizations can potentially provide a better overview of the result set. More importantly, search results visualizations can be combined with interactive elements to allow query reformulation and/or navigation. Strategies with a proven exploratory value such as dynamic queries, i.e. the instantaneous update of a visual representation by manual adjustment of filters (Shneiderman, 1994), and, most importantly, faceted search, i.e. the use of (hierarchical) categorical metadata for search (Yee et al., 2003), have further motivated our interest in an interactive presentation of search results.

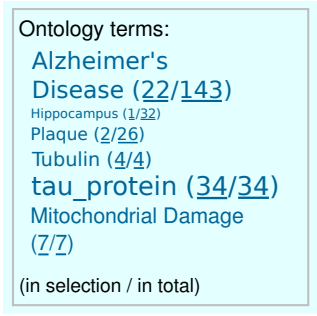
Straightforward information visualization elements were introduced in the CSIDx web interface to facilitate user interaction with the search results. Initially, search results were displayed as a list, in a sortable table of filenames or in a grid of thumbnails. While a standard design pattern, the list view lacks any overview of the results and provides no flexibility in refining the query. In response, the result page was redesigned and the standard result list has been updated with two new panels, the ontology term cloud and the modality graph (cf. Figure 2.7).

The ontology term cloud (cf. Figure 2.7b) is a list of all ontology annotations appearing in the given result set, presented in the popular tag cloud metaphor. Tag clouds, i.e. weighted lists of words, are typically related with folksonomies, i.e. sets of freely generated tags, but not with ontologies, which are highly structured. Yet, the tag cloud representation has some qualities that are of particular interest to our purposes. According to Sinclair and Cardew-Hall (2008), tag clouds can provide a visual summary of the corresponding dataset, while Rivadeneira et al. (2007) believe tag clouds to be suitable for impression formation, i.e. gaining a general understanding on a presented dataset. Furthermore, interactive tag clouds[3] can provide an easy way to browse, particularly in a non-directional, exploratory way (Sinclair and Cardew-Hall, 2008; Rivadeneira et al., 2007). Our ontology term cloud supports both browsing and query refinement by functioning as a combination of a tag cloud, in its popular form, and a drill cloud, as proposed by Newton (2008). More specifically, the user can either refine the current search

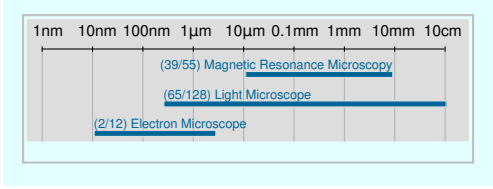
[3]When a tag cloud consists of hyperlinks instead of static words, clicking on a word stereotypically corresponds with a search for all items tagged with this word.



(a) The search results web page. Here, the results of a query for the ontology term 'Ovary' (NCI thesaurus). The web page provides a (paginated) list of results augmented with the ontology term cloud and the modality graph.



(b) Ontology term cloud



(c) Modality graph

Figure 2.7: Search results in CSIDx.

by adding another term to the current search or start a new search on a term. Terms in the ontology term cloud are weighted based on their frequency in the current result set. Per term, both the relative frequency, i.e. number of hits in the current result set, and the global frequency, i.e. number of hits in the entire (visible to the user) collection, are indicated.

The modality graph (cf. Figure 2.7c) is a dynamic graphic of the resolution range supported in the database. In the modality graph, all modalities present in a given result set are drawn at their approximate resolving ranges. Per modality, the number of hits in the current result set and the number of hits in the entire (visible to the user) collection are indicated. The modality graph allows queries on modality in a way similar to the ontology term cloud: The user can either add a modality restriction to the current search or start a new search on modality. While the resolution ranges are drawn only in approximation, the use of a resolution axis is a design choice motivated by the context and domain of the collection. On a sidenote, the modality graph is a lightweight interactive graphical representation generated entirely via CSS (Cascade Style Sheet) styles. As such, it was an early experiment towards web-native information visualization. At present, with significant advances in graphical support from within the browser, a number of toolkits deliver appealing, interactive, browser-rendered visualizations.

The above-mentioned panels emphasize the two major types of metadata in CSIDx, namely ontology and microscopy metadata. They visualize aspects of the data and result set that were previously out of sight and provide a means for the user to browse the result set and collection. Using simple interactive and visual elements, we are able to support a richer context for a given search. Eventually, the user is invited to examine the results and the collection as a whole rather than as an enumeration of individual entries.

2.6 Conclusion

CSIDx has addressed the challenges of biological image management and sharing by introducing semantic web technologies, i.e. ontologies. In effect, CSIDx proposes that a semantic image annotation that is both machine readable and human understandable will improve the management, sharing and integration of image data. Such tasks are dictated by the needs of biological research practice in general and the aims of the Cyttron project in particular. The emphasis given on metadata propagated into our understanding of (scientific) images: Images are not self-sustaining entities but composite entities of pixel data and metadata; the one (pixel data) should not be considered without the other (metadata). In

fact, most of the interactions we design are centred around (communicating or exploring) metadata. What is more, emphasis on ontology metadata resulted in a mental model of the CSIDx collection as a structure of interconnected entities that are linked together based on annotation. Such a vision was already prominent in the conception of the CSIDx and enforced by the nature and semantic potential of ontologies.

A thorough annotation by an expert, as required by CSIDx, is a task of considerable effort. During the development of CSIDx, it was apparent that we need to seriously support our users in the process of annotation. As the task can not be fully automated yet, a significant part of our support must be delivered in the form of a reasonable interface. The challenge of acquiring quality metadata in a user-friendly way remains formidable and will require the attention of HCI practitioners. Recent work on games for image annotation (von Ahn and Dabbish, 2004; Russell et al., 2008; Goh et al., 2011) indicates that costly operations need not always be painful; the applicability of similar ideas in CSIDx is still to be considered. Then again, it may be time for the CSIDx system to consider aspects other than data annotation, namely the access, retrieval and exploration of the available data. After all, the CSIDx system was conceived as a system for biologists to benefit from one anothers' research. To this end, more opportunities for 'consuming' the available data are needed. To date, we have provided simple, interactive visualization aids to better illustrate the CSIDx data (cf. ontology viewer) and collection (cf. search results visualization).

All in all, the context and background of Cyttron and CSIDx have greatly influenced our understanding of biological research practice and its needs. Evidently, both projects have impressed the significance of connectivity across image research material. As said, the Cyttron community is a manifestation of researchers wanting to learn from connections established across one another's images. Establishing connections by crossing modalities, subject matters or researchers is a highly desirable act. We extrapolate this idea to suggest that integration as linking, connecting, associating research material to other material or to new material is also a highly desirable cognitive act.

Chapter 3

Playing with images 1: Game-like interaction

Based on:

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A. Kallergi and F. J. Verbeek. Onto-Frogger: The making of. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, NordiCHI '10, pages 691–694, New York, NY, USA, 2010a. ACM

Abstract: In this chapter, we investigate video games as a platform for collection exploration, i.e. as a means to a more open-ended, exploratory interaction with a repository. We observe that video games can support both the relevant tasks, i.e. spatial navigation, and the relevant emotional state, i.e. playfulness, for collection exploration. What is more, we suggest that a more structural relationship between the game and the collection is possible: Rather than using games only as virtual spaces for navigation, we attempt to produce game logic according to the underlying graph structure of the repository. We explore these ideas on theoretical grounds and by means of a prototype game developed as a case study for the CSIDx scientific image repository. Onto-Frogger, our implemented game, is a game-like interface derived from a well-known arcade game. The chapter further documents the design, implementation and evaluation of our game. The resulting artefact is intriguing both as a product in the context of our database and as a tool to research the notion of game-like interfaces to collections.

3.1 Introduction

In most, well-maintained data repositories there is a potential for discovery. Think about it: Data repositories create opportunities for processes that are considered stimulating for discovery, such as (serendipitous) encounters with valuable items or the establishment of insightful associations between items. But if treasures lie hidden in data repositories, what tools do we need to discover them? This thesis considers tools or interfaces that can potentially empower the human user by creating opportunities for play and exploration. We advocate that play and exploration are interrelated and highly desirable acts to be facilitated by means of the interface.

There is a wide spectrum of activities that can be understood as playful or ludic. In fact, one can argue that any activity, even the most dull or tedious, can be exercised with a playful attitude, and thus be considered playful (Fullerton et al., 2008, chapter 4). Salen and Zimmerman (2004, chapter 22) propose an organization of play activities in three sets, each a subset of the previous one: Play as being playful, play as ludic activity and game play. In this chapter, we focus on the latest, i.e. on play as exercised within the formal structure of games. We consider games, more precisely, digital games, for both their entertaining value and their formal structure. Games are, after all, rule systems and we will attempt to couple their inner formal structure with aspects of the data repository. The final product should be understood as an actual game that (a) interfaces to a database and (b) channels information about the repository via its rules.

In section 3.2, we articulate why we expect video games to be relevant as interfaces for collection exploration. Our notion of collection exploration can be briefly summarized as an open-ended information activity for the sake of understanding. As we shall see, our interest in a game-like interface is developed amidst an ongoing interest in appropriating games for utilitarian purposes. Yet, we take this trend further by enforcing a tight relationship between the game and the underlying structure of the collection. In particular, we propose that a game may improve the user's mental model of the data organization, if the latter is properly encoded into the game logic.

Next to arguing on theoretical grounds, we investigate our ideas by means of an actual prototype. Specifically, we proceed with a case study for the CSIDx scientific image database described in chapter 2. The scope and context of the CSIDx repository are significant and so is the user group of the database, i.e. researchers in the life sciences. This chapter documents our path from a given database to a game concept to a final product. Section 3.3 presents Onto-Frogger,

our prototype game, and the rationale behind our game concept. Section 3.4 focuses on the development of the interface of the game given the Onto-Frogger game concept. Results from user evaluations are discussed in section 3.5 while section 3.6 summarizes our conclusions on the overall process.

3.2 Motivation

This section elaborates on the idea of video games as interfaces for collection exploration. We examine the nature of the intended interaction and the ways that video games can be relevant for such an interaction. Firstly, we discuss data collections as information spaces to be navigated in a playful and engaging manner. Secondly, we examine video games as potential 'executable' visualizations, i.e. as platforms that materialize structure and existing connections rather than visualizing them.

3.2.1 Games *for* data repositories: Gaming as exploration

What does an interaction for collection exploration amount to? Interfaces for exploration differ in focus and intention from typical search interfaces to collections and may require a shift from query-based search and fact finding. Consider as an example the exploratory search paradigm: The paradigm emerged in order to address different information needs, i.e. search processes of a high degree of uncertainty of the searcher (White and Roth, 2009), and as an attempt to facilitate learning and investigation (Marchionini, 2006). An interaction for collection exploration will require a similar shift towards more open-ended activities but will be more comparable to browsing than to searching. In information science, serendipitous encounters and associations, two of the processes that seem to contribute to discovery, are traditionally linked to (semi-directed or undirected) browsing or navigation in a hypertext-ed fashion (Foster and Ford, 2003). As summarized by Zhang (2008), browsing has a high degree of interactivity and can be understood as spatial movement across attention points.

We observe that video games can support such an open-ended interaction for collection exploration. To begin with, video games are closely related to navigation, as the notion of space is a central aspect of gaming, both philosophically and technically (Newman, 2004). Technically, gaming tasks often require navigation and wayfinding in virtual, usually three-dimensional, space. In fact, when information spaces are represented as three-dimensional spaces, navigation conventions from video games are applied for navigating these new spaces. This

is the case with various representations of digital collections such as libraries (Christoffel and Schmitt, 2002; Robertson, 2009) or museums (Anderson et al., 2009). We embrace the idea of collections as spaces to be navigated and note that video games can support tasks relevant for exploration, i.e. navigation.

Furthermore, video games can support the relevant emotional state for exploration. We believe that exploration requires a state of open-mindedness and even playfulness. Play is related in various ways to creativity and learning and, in the context of information systems, creativity and play may be beneficial towards serendipity and sagacity (André et al., 2009). Moreover, the field of HCI is bringing into focus positive affect, fun (Monk et al., 2002; Blythe et al., 2004) and playfulness (Kuts, 2009) as desirable aspects of interaction design. Of course, playful interfaces need not be video games, but valuable lessons can be learned from video games (Malone, 1982; Dyck et al., 2003) as good video games have shown to be very successful in user engagement. An extreme incarnation of a playful interface would take the form of an actual game: The notion of a 'game-like interface' was nicely exemplified in PSDoom (Chao, 2001), a Doom clone to administer computer processes. At the same time, various domains appropriate gaming practices in an attempt to tap engagement and attraction to video games. The serious gaming industry is developing video games for a variety of utilitarian purposes, from education to advertisement to social awareness (Susi et al., 2007; Alvarez and Michaud, 2008), while 'games with a purpose' as proposed by von Ahn (2006) attempt to convert human effort during play into productive work. Amidst such an interest in appropriating video games, we consider whether interfaces for collection exploration can be formed into video games to enhance user engagement and motivation and to benefit from the positive effect of fun and play.

3.2.2 Games *out of* data repositories: Gaming as information 'visualization'

Towards an interaction to support exploration, and, eventually, discovery, ideas and methods from the field of information visualization are relevant. Note that the primary goal of information visualization is to gain insight on data by exploiting our visual perception capacities. In the context of information visualization, exploration of an information space is related to activities that allow forming a mental model of this space, such as navigation and browsing (Spence, 2007). Similarly, Yi et al. (2008) suggest that one of the processes involved in gaining insight with visualizations is the formulation of a mental model of the data. According to Zhang (2008), information visualization can be beneficial for information retrieval as it

can capture useful information that is aggregated across items, on the macro-level of the collection. In line with the aims of information visualization, we believe that collection exploration should involve a better understanding of the collection and its structure as a whole instead of looking at individual entries only. For the purposes of this paper, structure can emerge by simply modelling the collection as a network of interconnected entities.

Typically, structure as in a set of entities and their relations is abstracted to a graph. The graph, i.e. a set of vertices and edges, is in fact a non visual representation. When visualized, a graph is represented as a node-link diagram using various graph drawing algorithms such as the ones surveyed by Battista et al. (1994). The node-link diagram is not the only possible graph visualization, see e.g. matrix representations discussed by Schulz and Schumann (2006). It is, though, the most prominent graph visualization and a great amount of research is dedicated in improving graph layouts in terms of both efficiency and user satisfaction. On the other hand, interactivity has allowed for interactive graph visualizations that enable exploration and direct manipulation; Herman et al. (2000) provide an instructive survey. Interactivity and navigation, e.g. across the graph and its available paths, are essential for constructing a mental model of the graph.

We have already discussed video games in relation to navigation. If graph structures have nodes to be visited and paths to be traversed, graph structures could as well constitute a game space to be navigated. But playing a video game is not only about spatial skills: It involves a variety of challenges that activate a plethora of cognitive processes. Can we exploit these processes towards a better understanding of the structure of the collection? We realize that several common games, particularly abstract strategy board games, can be described and analysed mathematically as graphs. In reverse, we question whether game logic can be devised out of existing graph structures, such as the connections in a data collection. Essentially, we introduce a more structural relationship between the game and the collection and propose that the underlying (graph) structure of the collection should be truly incorporated into the game. To this end, structure must be properly mapped to game logic and mechanics. For example, features of the graph could be utilized to control the progress of the game, to decide upon its outcome or to score the user actions. Such a game would confront the player with the structure of the repository during game time and would require the player to actively interact and reason with the encoded structure for the needs of the game. Eventually, the game becomes a form of 'executable' information visualization that materializes connections rather than visualizing them.

3.3 Onto-Frogger: A game *for* and *out of* the CSIDx database

We have designed and implemented a prototype game in order to investigate the suggested link between video games and collection exploration. Our case study is based on the CSIDx scientific imaging database described in chapter 2. The scope and context of the CSIDx repository are of particular significance: The aspects of the collection that are considered worth communicating are related to the data model adopted in the collection, mainly the semantic annotation of the image data.

3.3.1 The CSIDx database as a graph

Entries in CSIDx are composite entities: They consist of image data, i.e. pixel data captured from the imaging scanner, plus semantic information, as users annotate their images with ontology terms from various life science ontologies. The existing annotations can be exploited to impose structure across the repository and establish connections across images. Specifically, we model the repository as a (undirected) graph in which every annotated image is a node. Nodes are connected with an edge when they share an annotation term and multiple annotations are reduced to a single edge. Figure 3.1 shows a snapshot of the resulting database graph. In a sense, the resulting graph constitutes the semantics of our database: A gaming activity for CSIDx should support navigation across the interconnected images and familiarize players with the derived structure.

The current database graph is a minimal representation that can be further elaborated. For example, instead of reducing multiple annotation terms to a single connection, one can devise various rules on which annotations should contribute to an edge. Similarly, the graph extraction algorithm can be further extended e.g. by assigning weights to the edges or by calculating more sophisticated similarity measures among the images. Still, the current graph is sufficient as it exemplifies our idea that assigned image annotations impose structure across the collection. Note that a different graph extraction algorithm could help bring different aspects of the collection in focus.

3.3.2 Game design phase

To allow users to literally play with the repository structure, we need to provide a game that extracts both its content and its logic from the repository. In particular, the derived graph structure of the Cyttron database (cf. subsection 3.3.1) should

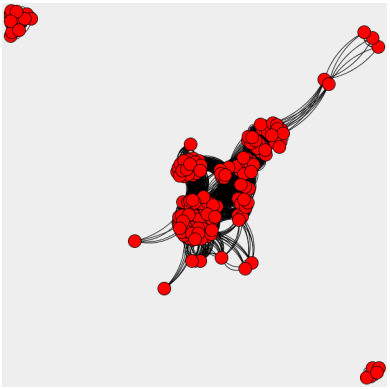


Figure 3.1: A snapshot of the CSIDx database graph (public and annotated images only) as of September 29th, 2010, rendered in the FRLayout. Nodes represent image entries and edges represent the presence of a common annotation term. The graph consists of 197 nodes, 4942 edges, 12 orphans and 3 connected components. The largest connected component has 165 nodes, 4827 edges and a graph diameter, i.e. longest shortest path, of 6.0.

be utilized to control the progress of the game, to decide upon its outcome and to score the user actions.

What kind of game would be appropriate for our purposes? As we abstract the collection to a graph structure, we sought for suitable game concepts in interplays between game tasks and graph tasks. Purely mathematical graph games played over a node-link representation do exist. For example, Bovey (2005); Bovey and Rodgers (2007) used the 'Shannon switching game' as a means to study graph comprehension across different graph layouts. However, such games will not scale up nicely to large graphs such as the ones expected in a data repository. More importantly, our focus is not on the graph visualization. On the contrary, we aim to submerge the node-link representation and communicate connections via game actions. At minimum, our game should allow 'visiting' nodes and edges of the graph in a game world. Tasks such as traversing paths and identifying neighbouring nodes are relevant tasks to be incorporated in and valued by the game logic.

As another requirement, our game needs to be simple enough to facilitate a primarily non-gaming audience. In a sense, we aim for a product that meets the characteristics of casual gaming regarding its requirements in skill and time involvement. With this in mind, we opted for adjusting an existing game concept instead of devising a new one from scratch: By appropriating a known game, we hoped to increase our chances for a successful final product thanks to a tested gameplay and/or a familiar look.

We have taken the classic arcade game Frogger (Konami Industry Co. Ltd, 1981) as a first vehicle for our own game concept. Frogger's concept (cf. Figure 3.2) seemed to be a suitable candidate for our purposes due to its popularity, simplicity and (implicit) path traversing qualities. The game is an arcade action game based on mechanic skill, i.e. timing of jumping and, in today's industry terms, would be best described as a platform game. Its interactivity can be formally narrowed down to dodging, i.e. the avoidance of moving objects, and obstacle course, i.e. the traversing of a difficult path (Wolf, 2002). To put it differently, the game requires the player to execute a valid trajectory in game space. In addition, an analogy with Frogger could lower the entry threshold for our users. The game is of iconic status and its popularity and familiar look should help our users to quickly comprehend the new game. Its simple controls and minimal storyline should aid even the non-gamer to immediately start playing.

3.3.3 Onto-Frogger, the game

Onto-Frogger, our prototype game, is a single-player, arcade style game. It borrows the game settings of the classic arcade Frogger but enhances the original action-based gameplay to include images and their annotations. In particular, the game focuses on the user annotations with ontology terms and on the connections implied by these annotations. The result is a crossover between an action/platform and a puzzle solving game. The game aims to familiarize the players with the idea that images in a (semantically enriched) collection are interconnected and to invite them to identify, predict and resolve various connections during gameplay.

In Onto-Frogger (cf. Figure 3.3), the player needs to reach a target image on the other side of a river. Arriving at the opposite bank requires the player to land successfully on image tiles, i.e. without getting drowned, and to collect enough coins on the way in order to pass the toll station on the other side. Coins are to be found on image tiles that share annotations with the target image: Every coin is an annotation term shared with the target. The objective of the game is to jump on appropriate image tiles that grant sufficient coins and to collect as many coins as possible in order to achieve a high score. Collecting multiple unique annotations (golden coins) is rewarded more points than collecting multiple instances of the same annotation (silver coins).

Technically, the so-called 'coin terms' are edges to the target image: Making a successful trajectory directly relates to visiting neighbours of the target node which can be understood as the target's immediate context in the repository.

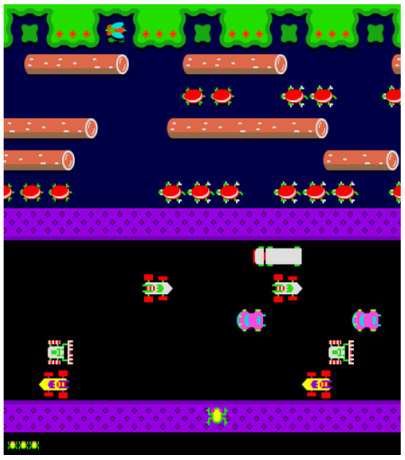


Figure 3.2: Frogger-like gameplay. The player's task is to guide a frog to its nest while avoiding a variety of threats on the way. Moving from the bottom of the screen to the top, the frog needs to cross over a busy highway, by avoiding the passing-by traffic, and then over a river, by jumping on floating objects, in order to reach the opposite bank. Technically, Frogger is an action game based on mechanic skill (timing of jumping) and, in today's industry terms, would be best described as a platform game (Frogger clone implemented by neave.com).

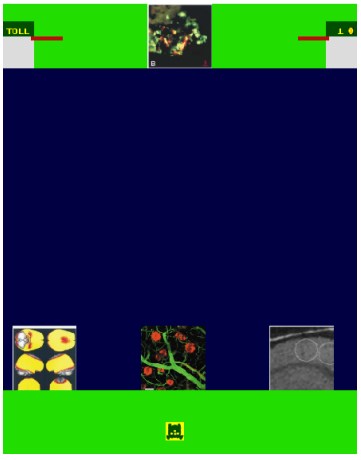


Figure 3.3: Onto-Frogger (2009), active area upon game start. The frog needs to cross the river by jumping on floating image tiles using the target image as a guide. The target image is inaccessible behind the toll station as no coins have been collected yet.

With respect to mapping graph elements to game mechanics, the game focuses on the graph edges, i.e. presence of a connection, which are translated to the game interactivity of collecting. The game also implements the traversing of a graph path as each subsequent lane consists of image tiles connected to the preceding image tile. The introduction of a coin constraint was suggested by the features of our dataset, namely a very dense graph with short distances. As a result, Onto-Frogger evolved into a more elaborate game that deviates from its original inspiration.

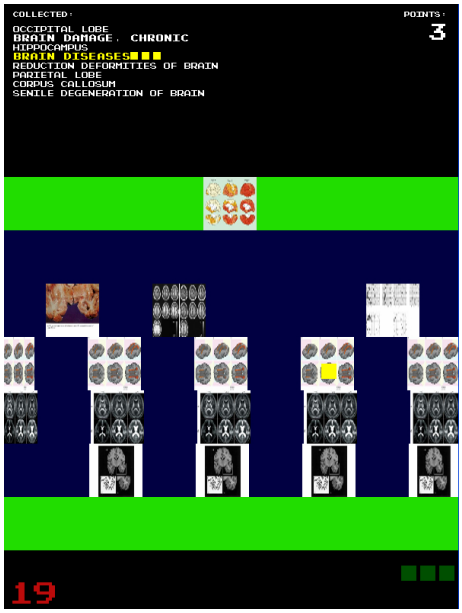
Onto-Frogger is programmed in Processing (Reas and Fry, n.d.). Processing is a subset of Java suitable for quick prototyping thanks to its excellent support for programming visuals. The graph-related functionality of the game is supported by the Java Universal Network/Graph (JUNG) framework (O'Madadhain et al., 2005). The game runs as an applet embedded in the web interface of CSIDx and it is available online for registered users of the CSIDx database.

3.4 Meeting the requirements: Refining the interface of Onto-Frogger

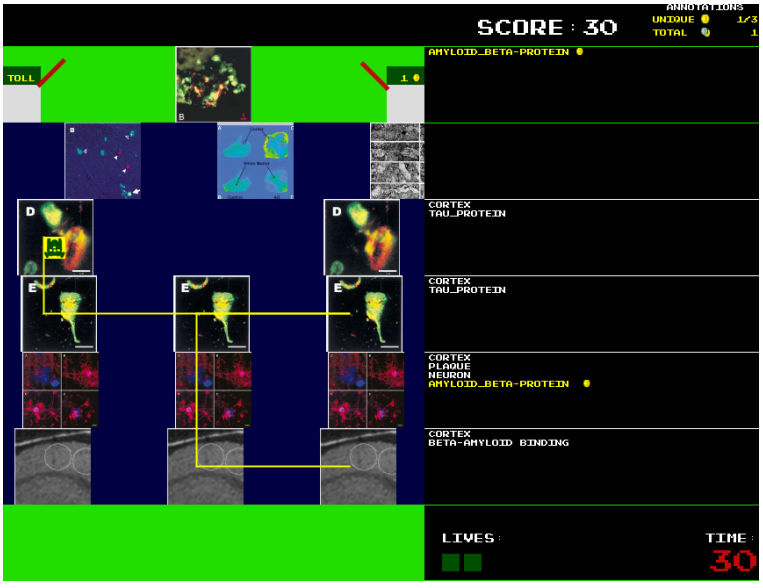
In this section, we focus on the interface of the game, i.e. on the development of a user-friendly product given a concluded game concept. In a way, we try to ensure that interface issues are not in the way of our game before questioning the validity of the game concept itself.

All in all, we believe that interface issues matter. Considering Onto-Frogger as a research prototype, it is only reasonable that we eliminate bias in responses due to interface flaws. Considering Onto-Frogger as a product, i.e. a game-like interface to a collection, its interface is central for the user experience. First, usability is a matter of concern to all video games as it can greatly affect the player's experience (Pinelle et al., 2008). Second, a game that is also an interface to a collection must provide a clear and legible information display for the data communicated. Last, the game should be straightforward enough to allow non-gamers to immediately start playing. Simplicity in controls and gameplay is directly related to the game concept but providing a self-explanatory game environment is mainly an interface issue.

A first version of Onto-Frogger's interface (prototype A, cf. Figure 3.4a) was used to examine how understandable the new game is. Two users (1 biologist, 1 computer scientist) were asked to play Onto-Frogger and figure out its rules without prior explanation. The results were discouraging: Our players did not



(a) prototype A



(b) prototype B

Figure 3.4: Prototype A vs prototype B. Collected annotations from each selected image tile are now displayed on the right panel and for each lane separately. Coins are designated on each lane and on the score summary.

Table 3.1: Major changes between prototype A and B.

type	prototype A	prototype B
layout	collected annotations and coin annotations appear on the top left part of the screen	collected annotations and coin annotations appear on the right panel of the screen
layout	collected annotations and coin annotations displayed in a term cloud	collected annotations and coin annotations displayed per lane- a HUD display summarizes the total accumulation of coins
graphics	player is a yellow square	player is a frog
graphics	yellow squares as coins	coin icons- visual distinction between silver and golden coins
narrative	-	toll station added
training	-	tutorial with in-game training

realize that a coin rule was enforced and were very frustrated when losing the game due to a lack of coins. Simply put, they were only trying to play Frogger but not Onto-Frogger. During this evaluation, we identified several interface flaws that may have obscured the significance of coins in the game. We, therefore, suggest that our players did not resolve the rule of collecting coins simply because the interface failed to place coins in focus.

In response, we re-designed the interface so that collected coins are more prominently placed. A comparison of the in-game screens of the two prototypes can be seen in Figure 3.4. Moreover, we decided to count less on the analogy with Frogger and treat Onto-Frogger as the new game that it rightfully is. Eventually, we included a complete tutorial with supportive text and storyline. The new prototype (prototype B) was subject to expert evaluations by 5 HCI literate users[1]. This evaluation was focused on the clarity of the in-game interface and tutorial, as also suggested by Pagulayan et al. (2003). Proposed improvements were further incorporated in the current version of the interface. Major differences between the two versions of the interface are summarized in Table 3.1.

A special note should be made on the look and feel of Onto-Frogger. From early on, we were aware that the resulting product should be perceived and accepted as a 'real' game. To this end, a proper look and feel of the game and consistency with gaming conventions are essential: The interface should look like a game and play like a game. Respecting industry conventions in controls is a frequent guideline in game design (Desurvire et al., 2004; Federoff, 2002) and we strive for consistency in terms of controls and feedback as well as of visual and sound design. Throughout the development of Onto-Frogger, we were fortunate to conduct expert evaluations with a game developer who reported on gamer expectations (e.g.

[1] All testers have been employed as assistant personnel for the HCI course taught in our department.

button response) and commented on the style of the game. Obviously, the look and feel of Onto-Frogger mimics that of Frogger and of arcade games in general: The visual style, game controls and soundtrack of Onto-Frogger were selected accordingly. This intention is apparent in both versions of the interface (cf. color schema and coin sounds) but prototype B improves on the graphics, within the aesthetics of the genre.

3.5 Results

3.5.1 User evaluation

The two versions of the interface were further evaluated by four novice users (4 life science students), new to both the game and database. In think-aloud sessions, the players interacted with the web interface of the database, the original Frogger game and prototypes B and A, in the given order. Prototype A was introduced as a game that may or may not have the same rules as prototype B. Both prototypes were assessed by a questionnaire including also open questions to test the players on the rules of the game.

While results are only indicative, we are pleased with quality of the current version of the interface. Overall, Prototype B is better received in terms of legibility and clarity as well as look and feel of the interface (cf. Table 3.2). With respect to the major aim of the re-design, i.e. to better support the learning of a game by means of interface improvements, we observe that prototype B allowed all players to resolve the game rules accurately. Prototype A, on the other hand, introduced confusion, particularly due to the absence of coin icons (cf. Table 3.2), but our players did not have as much difficulty as previous testers of prototype A. This observation does not render prototype B redundant since the players highly valued and often commented on the missing features. Instead, it may be an indication that prototype B allowed players to successfully internalize the game rules, a knowledge they could later use when interacting with a less supportive interface.

Interestingly enough, prototype A seems to score better that prototype B in terms of user satisfaction. Previous observations suggested that a clearer interface and, hence, a more understandable game would increase satisfaction. Our players appreciated prototype B more, visually and in terms of clarity, but found prototype A more challenging and more fun to play. The players themselves justified their preference to an increased speed of the passing tiles in prototype A. Such a feature should be easy to implement in prototype B, but it may indicate a conflict in the aims of our game: A faster pace has been in times perceived both as a welcome

Table 3.2: Relevant quotes extracted from think-aloud session (audio-recorded) and questionnaires (player id indicated as P#)

topic	quotes
interface: graphics	"a frog is better than a square" [P1], "I liked playing with a frog better than with a yellow square" [P3]
interface: graphics	"This [prototype A] is less easy to understand because there is no coin system, it only shows a few squares and they are all the same color, so it's a bit difficult to tell how many points you got and how you really got them" [P3]
gameplay: challenge	"I understood the first game quicker but at least this [prototype A] is a bit more challenging" [P3], "[prototype A] is faster... I think it's better... because it's more fun" [P1], "let the tiles come by faster because it takes a lot of time to see them all, it was better the second day" [P4]
gameplay: challenge	"if you are getting good at it, it will be fun to turn up the speed or reduce the amount of time" [P1]
mental model	"you have to understand that the tiles have connections with each other" [P1], "in how annotations are sort of linked" [P4]
mental model	"you can learn to relate pictures to text and annotations and you can relate back from annotations to pictures to get the search results you want" [P2], "what kind of annotations are required to find certain images" [P3]

challenge and as a hindrance in studying the available information. Of course, increased satisfaction could simply result from previous exposure to the game: The players, free from the load to understand the game, could now enjoy playing and would even request more challenges. Further ideas to expand gameplay with new rules or new levels are still to be considered. But the exact impact of the interface on perceived challenge is yet to be determined. Would e.g. a more adaptive interface, i.e. one that simplifies its layout as the player becomes familiar with the game, be more appropriate for our purposes?

3.5.2 Impact

Onto-Frogger (and any other game for collection exploration) is a challenging product to evaluate, due to both its hybrid character and its aims. Being a channel of information and a potential source of discovery and insight, Onto-Frogger should be evaluated with respect to the effect of its use. However, evaluating the exploratory potential of our game is a cumbersome task; the challenge is comparable to the ones faced in evaluating information visualization displays that aim to promote insight. As noted by (Saraiya et al., 2005), evaluating for insight is further complicated by the nature of the creative processes to be stimulated and may require longitudinal studies on the use of the product over time.

Anecdotal evidence, though, seems to support our ideas on the contribution of the game as an 'unconventional' interface to the image collection, especially on its impact on the user's mental model. Overall, all of our student players

reflected on the collection as a connected structure and discussed the game rules in terms of establishing links between images (cf. Table 3.2). At minimum, the game does not fail to communicate connections. But the most promising potential of Onto-Frogger lies in the confrontation with the image annotation process. By interacting with the game, the players eventually reflect on the varying quality of the annotations and the different annotation strategies. Consider, for example, the following remark: One of our expert players argued that the game is inherently unfair as different images have different numbers of terms assigned to them and, hence, permit different score maxima. The observation was repeated by one of our student players, who noted that "the point system isn't completely fair". The player also observed that "sometimes only one golden coin could be collected which was needed to win" which was more difficult to achieve. The player actually proposed strategies to normalize the score but we are reluctant to correct this inherent unfairness. Another expert player complained that an obviously right image choice was not rewarded as such because the image has been annotated differently by its owner. These discussions are highly desirable in the context of our database and were entirely triggered by the game. By converting an aspect of the system into something relevant for the player, e.g. score, the game enabled the player to react on an important aspect of the system, i.e. annotations. Such exposure to the database's principles has a considerable educational potential considering that annotation of image entries is a central task for users of the CSIDx database. To date, we are still to examine the (long-term) usage of the game by users who are actively involved with the database. But, all in all, we believe that Onto-Frogger can have considerable educational capacities and can at least serve as a good introduction to our database.

3.6 Conclusion

Onto-Frogger is a product that can be examined at various levels of abstraction: As an interface, as a game, as an information channel and as an exploratory experience. At present, we can safely discuss Onto-Frogger at the interface level: Onto-Frogger has matured into a usable and legible product, whose in-game interface is, according to the requirements, explanatory of the game rules. We know less about Onto-Frogger as game: We are not sure if Onto-Frogger is a good game concept and, more importantly, if it is a proper game concept for the given graph structure. Surely, Onto-Frogger is readily accepted as a game, contains a game space that is directly derived from the graph structure and directly maps the identification of graph edges to game rules. But we have yet no means to compare

alternative game concepts in terms of how well they suit our dataset. Finally, we have a glimpse on Onto-Frogger as an 'executable' information visualization and, correspondingly, as an exploratory interface: The game seems capable of materializing the collection as an interconnected structure and of exemplifying that images in a (semantically enriched) collection are interconnected. What is more, the game seems to contribute to the user's mental model of the data collection not only by materializing structure, as suggested, but also by its unindented educational quality on the topic of image annotations. In effect, playing the game confronted the players with the shortcomings of insufficiently annotated data and enabled them to reflect on a fundamental aspect of the repository, contributing to a better understanding of the collection and its underlying data organization.

As already explained (cf. section 3.4), there are various reasons why our iterations and evaluations have focused on the interface level of Onto-Frogger. Let us repeat here that we believe usability to be relevant for the gaming experience, if only for avoiding player's frustration. Of specific concern to our purposes are the notions of legibility, relevant for information display, and learnability, relevant for supporting users who are not necessarily gamers. In Onto-Frogger, where a considerable amount of information is communicated, we observed a tension between information processing and the tempo of the game. Arguably, this may be due to the game genre appropriated, i.e. arcade action game, rather than the design of the in-game interface. Nevertheless, we would like to further study the impact of the interface on the player's experience in general and on information processing in particular. Note that Onto-Frogger's in-game interface will appear 'busy' to advocates of minimalistic and integrated user interfaces for games. Then again, the game design community is torn between polemicists and proponents of non/transparent interfaces for games (Jørgensen, 2011). Still, the need for efficient information management in game interfaces is real and relevant not only to our own particular, data-oriented product but to information-dense commercial games as well.

To some extent, our emphasis on interface issues is associated to a lack of a standardized methodology. Onto-Frogger was an experiment and a research tool to tackle an unexplored territory, i.e. making games out of the graph structure of the collection for the sake of exploration. At present, we lack both a robust methodology to design such games and a framework to evaluate them. A layered evaluation approach may not be foolproof but it is, at least, a start. Note that the validity and impact of game-like interfaces for collection exploration could be properly researched only by means of a proper prototype. Then again, a 'proper' prototype must be not only a flawless interface but also a challenging and suc-

cessful game. We are aware that our emphasis on eliminating interface flaws may have side-tracked us from exploring more game concepts.

Process-wise, Onto-Frogger's game concept was the outcome of creative brainstorming together with a close inspection of our dataset. An analogy with a known concept was expected to facilitate the design process but we have learned that it is the features of the graph that dominate the game design. Of course, there are multiple ways we could improve our design methodology. In the tradition of information visualization, where effective encodings of certain types of data to certain visual attributes have been proposed, we are curious if one could formalize and validate effective mappings between graph elements and game elements. Compiling a vocabulary of graph metrics and tasks versus a vocabulary of game mechanics and elements should be a manageable undertaking whereas validating the effectiveness of potential mappings will be a major challenge. On the other hand, we realize that a more user-centred approach may be more suitable for our purposes. As a matter of fact and during our conducted user tests, our testers would propose new and interesting game rules when attempting to resolve the actual game rules. We suggest that involving the players early in the game concept phase is a strategy worth exploring.

Onto-Frogger was first demonstrated in the 'Semantic Web Applications and Tools for Life Sciences' (SWAT4LS) workshop in 2009 (Kallergi and Verbeek, 2009); its development ended in 2010. In the meantime, new and relevant developments emerged. Within the context of 'gamification' (Deterding et al., 2011), Diakopoulos (2010); Diakopoulos et al. (2011) propose the concept of 'game-y [sic] infographics', i.e the amplification of infographics with gaming elements. The authors see infographics as storytelling experiences crafted by a designer and are thus interested in gaming elements as the means to a more structured, interactive storytelling experience with the data. Like our approach, the authors acknowledge that a mapping between game mechanics and visual analytics tasks is required; our approach is analogous but oriented to tasks applicable to graph structures. More importantly, we compose an entire game and game world based on our data instead of layering an infographic with game elements. At the same time, we are particularly encouraged by the concept of 'playable data' and its potential role as a valid information visualization strategy.

Chapter 4

Play and exploration in image collections: A Flickr-based study

Based on:

A. Kallergi and F. J. Verbeek. The games Flickrites play: An investigation of Flickr-based gaming activity with special focus on opportunities for exploratory interaction. In Proceedings of the IADIS International Conference Game and Entertainment Technologies 2011, pages 35-42, 2011

Abstract: What kind of games do people play with digital images? To probe this question, we examine image-based gaming activity as exercised in the Flickr photo sharing system. Noticeably, a surprising number of user-moderated games are being played within the structure of Flickr groups. We provide an assessment of this activity and a first categorization of the exact types of games played: Recurrent themes are observed and discussed. Furthermore, we examine gaming activity in the scope of collection exploration, looking for opportunities that may stimulate or engage the player to explore an image collection. Being interested in playful interactions with images and in games as a platform for exploration, we question if the games played can support collection exploration. Potentially promising ideas as derived from the current Flickr gaming landscape are grouped, reported and discussed.

4.1 Introduction

An invitation to play is an invitation to explore. In the context of data collections, where a potential for discovery and a need to explore are substantial, exploration can benefit from a more playful and open-minded attitude of the (re)searcher. Technically, exploration relates more to undirected, open-ended information activities such as browsing and is often exercised as movement across information space. Precision is not always the key: Getting an impression of the collection as a whole, following related or connected items, landing at unexpected but useful items, establishing serendipitous connections between items can all trigger a feeling of discovery. In order to design interfaces that will challenge and engage the user to explore, we believe that ideas from play and games are worth exploiting. In chapter 3, we observed that gaming can support both the relevant tasks, i.e. navigation, and the relevant emotional state, i.e. positive affect, for exploration. Our research aligns with the increasing interest of the HCI community towards more playful interfaces: Currently, much attention is given to the potential of applying gaming elements in different contexts including application software. Consider as an illustration the classic work of Malone (1982) pollinating HCI with gaming elements, recent studies on funology (Blythe et al., 2004) and fun in the interface and the numerous examples of serious games (Susi et al., 2007; Alvarez and Michaud, 2008), games with a purpose (von Ahn, 2006) and game-like applications. We are particularly interested in the 'gamification' (Deterding et al., 2011) of interfaces to image collections and in 'gamification' as the means to promote collection exploration. In chapter 3, we engaged in implementing suitable gameplay for collection exploration. Nevertheless, we find it useful to examine what lessons can be learned from existing practices in popular image collections and from existing games involving digital images. We hope to be able to extrapolate our findings to further support playful interactions with image collections.

For the researcher interested in interactions with image collections, Flickr (http://www.flickr.com/) is one of the obvious choices to study. Its popularity and success are phenomenal. Flickr is one of the major photo hosting and sharing systems and one of the top visited websites worldwide, with a large community of users and a vast collection of images. Official statistics are not available but Flickr is rumoured to consist of over 30 million registered accounts (Flickr: The Help Forum, 2009); the 5-billionth photo was reported on September 2010 (Zack, 2010). More importantly, Flickr has been a fruitful and influential platform for social web practices, such as tagging, social networking and social browsing. Daily, a substantial number of users are uploading, annotating, browsing and

commenting photos in Flickr, while a great deal of social interaction is taking place via features such as favourites, comments and groups.

Play and playfulness have a noticeable role in the overall interaction with Flickr. According to Velasco-Martin (2009), "one of Flickr's main strengths, beyond being highly usable, is that it is fun, since they were somehow capable of conserving its playfulness, which is key for its user participation". Similarly, in "Flickr is a MMORPG" (cited by Fake, 2004), the commentator enumerates the striking similarities between a typical game and Flickr: "Flickr is inherently, down-to-its-bones about play. If you look at a list of the elements of a successful game, they are all present in Flickr: a sense of space to explore, a range of challenges, a range of abilities which can succeed [sic], the need for preparation and skill, a variable feedback system". Taking a slightly different approach, Mäyrä (2008) analyses Flickr as a game of paidia, i.e. as an activity of less competitive but playful and game-like behaviours to support online photo sharing.

If the core of Flickr's interaction is infested by such implied play, the platform is also associated with a number of explicit play activities that use the Flickr collection and system. In one hand, the Flickr API has allowed a considerable amount of programming activity for external applications that use the Flickr collection. Many of these applications are simple, image related games. External games are hosted and maintained by their developers and reside outside of the Flickr system. On the other hand, the platform itself, and specifically the format of groups (cf. Figure 4.1), is extensively utilized for playing simple image games. This study will exclusively discuss gaming activity exercised within Flickr groups. Our interest in group gaming activity is two-fold: Firstly, groups are noteworthy community spaces and are often associated with entertainment (Stvilia and Jörgensen, 2007). Secondly, group games are initialized and moderated by Flickr users themselves. This allows for freedom and flexibility in setting up or adjusting the games, which we hope to provide us with a better insight into the needs and preferences of the players. Nevertheless, it is exciting to observe how members in a self-organizing system provide playful means to interact with the system.

The rest of this paper is structured as follows: An examination of the types of gaming activity exercised across Flickr groups and a first look into the exact types of games played is given in section 4.2. Reoccurring themes and distinguishing game concepts are identified and discussed. In section 4.3, we examine one particular 'genre', i.e. associative games, to contemplate on the potential of gaming as exploration. Conclusions and points of discussion are given in section 4.4.

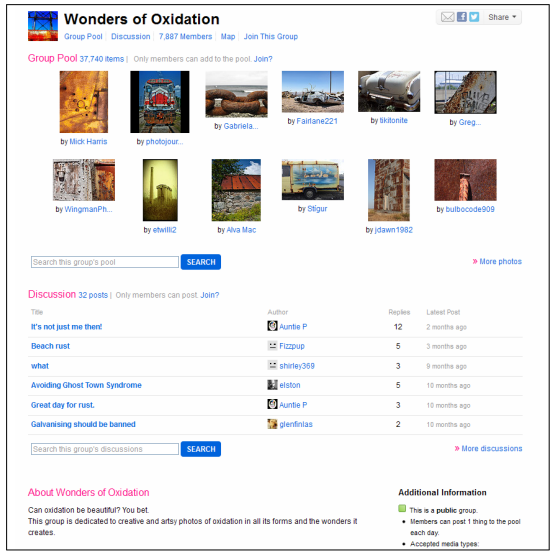


Figure 4.1: Entry page of a typical Flickr group (partial view). Here the 'Wonders Of Oxidation' group, a group dedicated to photos of oxidations (group URL: http://www.flickr.com/groups/52239914863@N01/). Depending on the rules of the group, group members may contribute content to the image set of the group (group pool) and may participate in discussions held in the message board. Screen captured: 05-08-2012.

4.2 The games Flickrites play

During the period September - November 2010, we reviewed a potentially relevant subset of Flickr groups and the gaming activity they employ. While manual and, consequently, only indicative, this examination verifies the extent of gaming activity taking place in the Flickr universe and provides us with a first yet informative look into the characteristics of this activity. The data examined in this section are available at http://bio-imaging.liacs.nl/galleries/iadis2011/.

4.2.1 Collecting and examining groups

Potentially relevant Flickr groups were retrieved by querying the Flickr interface for the terms 'flickr games', 'photo games' and 'games' with added restrictions (cf. Table 4.1). The ambiguity of the concept 'game' and the limitations of the Flickr search severely impaired the precision of our queries, the results of which required further manual filtering. Out of the overwhelming number of results, a maximum of 500 results per query were retrieved. Duplicate retrieved results, groups with insufficient number of members (<= 1), non public groups and non English speaking groups were programmatically removed. Subsequently, groups with obviously irrelevant topics based on their title or description were manu-

Table 4.1: Queries submitted via the Flickr API interface. A maximum of 500 results per query were retrieved for further inspection. Results were refined using both programmatically accessible attributes (e.g. number of members) and textual information of varying level of detail. The group titles, the group descriptions and, eventually, the discussion threads were examined in the given order.

Query	Date	Hits	Retrieved
flickr games	16-09-10	2506	500
"flickr games"	16-09-10	20	20
"photo games"	16-09-10	54	54
games -video -videogame -playstation -xbox -nintendo -sport -olympic -cards -board -toys -rpg	15-09-10	7037	500

ally removed. Examples of irrelevant topics encountered are sport events, toys, videogame screenshots, videogame conventions, game reserves and many more. After several manual filtering iterations, the original result set was reduced to 166 relevant groups for further analysis. Relevance of a group or activity was often assessed with respect to the intent of its initiator, i.e. explicit reference to a game and its rules. All 166 groups make claims to some sort of gaming activity within their setting; however, their understanding of the concept of 'play' is varied.

The description texts of the examined groups in combination with their message boards suggest certain reoccurring themes. Specifically, it appears that most of the groups relate to any of the following themes:

1. Gaming as secondary activity: Groups of various topics may play games as threads in their message boards. These groups engage with unrelated to gaming topics (e.g. photos of boxer dogs or flowers) or communities (e.g. a group of Canberra based photographers) but provide or permit some entertaining diversion in the form of threaded games.
2. Gaming as core activity: A number of groups are specifically created for the purpose of playing 'casual' games among their members. Several variations in the organization of these dedicated to gaming groups are possible. For example, dedicated groups can maintain collections of several known threaded games; such collection groups are often suggested as central hubs to play games otherwise scattered around Flickr. Other groups maintain multiple instances/threads of the same type of game in their message board. Finally, many dedicated groups are single instances of one game, played in the pool (image repository) of the group, rather than in the message board.
3. Gaming as contest: A number of groups are specifically created for the purpose of conducting image challenges and contests. Such activities are usually periodic, accompanied by strict posting rules and voting procedures and resolved with the announcement of a winning photo. A less formal variation of this theme is found in groups that require their members to

award, rate, comment or favour images of other group members. While different in their organization, these groups also structure their play around rating the quality of one another's images.

4. External gaming activity: Groups may engage in games or playful activities that are photo-oriented but performed outside the Flickr system. Consider, for example, scavenger hunts that require players to shoot a list of given subjects in limited amount of time. In such cases, the group usually serves as a reference point for instruction and coordination and as a container for the submitted image entries.

Examples of groups that are representative of the above themes can be found in appendix A.

Groups dedicated to 'casual' games (theme 2), challenge/rate groups (theme 3) and container groups (theme 4) are all primarily engaged with playing with images and could be all filed as dedicated to gaming. Yet, we find useful to distinguish these varied understandings of play. External gaming activity, although potentially creative, will not be further discussed; focus is on games that utilize the existing Flickr database. Challenges and contests are labelled distinctively from 'casual' games due to their particular focus on judging and voting. Gaming as secondary activity (theme 1), however, is a discrete theme and can be easily intertwined. For instance, there exist challenge groups that also play 'casual' threaded games. For the purposes of this study, an exclusive classification of the groups is less important than observing the various functions and forms of playing as suggested by the users.

4.2.2 Collecting and examining games

We further look into the types of 'casual' games played as either core or secondary activity. First, we look into the threaded games played (cf. Figure 4.2) and, then, extrapolate our findings to groups dedicated to one type of game only. To collect games, we used all 10 groups with core gaming activity that maintain game collections and 2x10 random groups with secondary gaming activity; these group are expected to play threaded games only. The message boards of the groups were queried via the Flickr interface for the term 'game'. Again, the notion of game in the retrieved threads is not clear-cut. Similarly to the various forms of play in groups, we encountered various activities such as challenges/contests or themed showcases among the results. In consistence with our earlier distinction, pure contests and themed threads as well as overt requests for comments were not considered for further inspection. Moreover, we found numerous purely word-

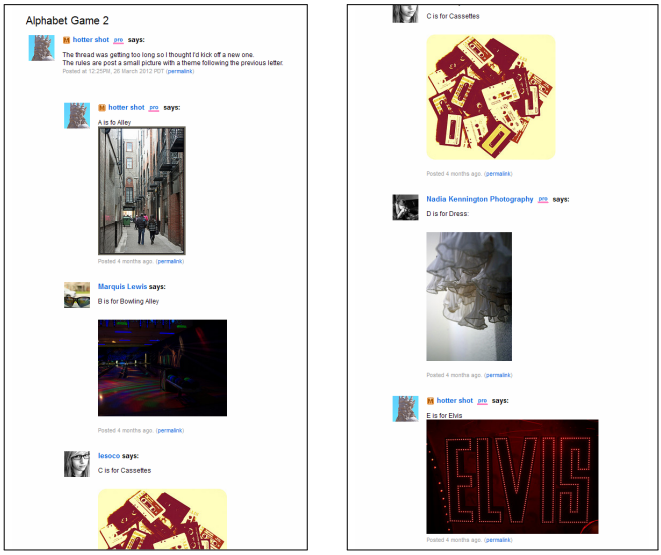


Figure 4.2: Threaded game played in the message board of the group (partial view). Here an instance of the ABC game played by the 'Flickr For Fun' group (group URL: http://www.flickr.com/groups/flickrnewpictures/). In threaded games, players typically post their moves as replies to an ongoing thread with played images included as thumbnails. Screen captured: 05-08-2012.

based games, which are worth mentioning but are irrelevant to our study as they incorporate no images in their gameplay. Word games were excluded but image variants of those exact word games were retrieved.

According to our retrieved set, a number of popular threaded games tend to reoccur across groups. Table 4.2 provides a list of the most frequently played threaded games, presented under their generic names. In most cases, the exact same game appears under different names, e.g. the ABC game was found as the 'Alphabet game', the 'I am going on a picnic and I am bringing...' game, etc. In some cases, slight variations in the rules occur (e.g. count to 10 or to an ever increasing number) but the core of the game remains the same. A frequent variation, particularly in groups with secondary gaming activity, is to play known games with a subset of images relevant to the interests of the group, e.g. the 'NJ-New Jersey' group plays known games with New Jersey related images only. All these easily identifiable variants were filed under their generic names.

A closer inspection of the collected threaded games reveals a rather limited range of game concepts. For example, in both the ABC and the 'Last letter' game, the subject of the next image should start with a given letter. The two games differ in the way the next letter is produced, but, in both cases, the response is illustrative of a triggered subject. We attempt to capture such similarities in the core

Table 4.2: Top-10 most frequent threaded games filed under their generic names. Given frequency reflects the occurrences of the same game concept across multiple groups, not the number of game instances within the same group (can be more than 1). Collections: Groups dedicated to gaming that maintain collections of threaded games. Secondary: Groups that play threaded games as secondary activity.

Generic name	Rules	Collections	Secondary (1)	Secondary (2)
ABC	Post an image whose subject starts with letter L, L increases alphabetically	7	6	6
I spy	Post an image that depicts a subject spied in the previous image	6	6	5
Person above you	Post your favorite image from the previous person's photostream	3	6	6
Photo association	Post an image that relates to the previous image	5	1	3
I request a...	Post an image that depicts the requested subject	4	1	1
Rainbow	Post an image with color C, C follows the rainbow	4	1	2
Count	Post an image that shows X items, X increases	3	1	3
Last letter	Post an image whose subject starts with letter L, L is the last letter of the previous subject	2	0	0
Spell shot	Post an image whose subject starts with letter L, L moves along the letters of a given word	1	1	1
Name my photo	Give a name/title to an image	1	1	2

rules of the games by deriving a number of representative game concepts/genres. Our focus is on the function of images in the game: What is the player expected to do with respect to (an) image(s)? What is the contribution of a posted image in the progression of the game? Our proposed concepts are described in Table 4.3.

Table 4.3: Proposed game genres/concepts, in alphabetical order. The verbs proposed are representative of the activity required by the player during the game and with respect to images.

Category	Description	Examples
associate	Post an image response to the previous image post: Construct a chain of responses	Photo association , I spy
create	Produce images, mosaics, etc.	Flickr-Wikipedia game
guess	Guess the subject of a given picture	Guess what? Guess where?
illustrate	Illustrate a (requested) subject, subjects produced by current or previous player	Count, Alphabet, Last Letter, I request a..., Opposites
reflect	Reflect on a posted image or on a photostream (note: simple feedback threads were excluded)	Person above you, Name my picture

The proposed concepts were used to label all retrieved game threads (cf. Table 4.4). Also, we label the groups dedicated to one type of game (cf. subsection 4.2.1). Once again, our approach when applying genres is a deliberately image-centred one. For example, games labelled as associative require that the next move in the game is an image response to an image stimulus from the previous move. However, there exist word association games that ask the player to respond to a text stimulus with a text response accompanied by an image. Technically, the function of images in these games is illustrative. Still, it is difficult to assess the impact of the accompanying image on the response of the player: It is likely that, in the presence of an image, a player does not solely respond to a text even if supposed to.

On a side note and after having examined all collected threaded and single games, we comment on a few technical aspects of Flickr-based image games. Generally speaking, Flickr games are either endless or artificially terminated by means of time or number of posts. Players take turns in arbitrary order but limitations apply on the number of posts per player or the number of posts in between a player's next move. Overall, threaded games are simple, linear and easily identifiable. Single games, on the other hand, seem to demonstrate more variety in their concepts and in their rules. For the sake of comparison, Table 4.5 shows the 10 most frequently played games across single game groups. While the most frequent threaded games (cf. Table 4.2) are predominantly of the 'illustrate' genre

(associate= 2, illustrate= 6, reflect= 2), single games seem to demonstrate more variation in player activity (associate= 3, create= 4, guess= 2, illustrate= 1).

Table 4.4: Games identified per concept. Collections: Groups dedicated to gaming that maintain collections of threaded games. Secondary: Groups that play threaded games as secondary activity. Single games: Groups dedicated to gaming that play one type of game only.

Category	Collections	Secondary (1)	Secondary (2)	Single Games
associate	14	7	8	19
create	1	2	1	12
guess	1	3	2	20
illustrate	29	12	13	8
reflect	8	8	9	1
not categorized	6	2	1	2
total	59 games	34 games	34 games	62 groups

Table 4.5: Top-10 most frequent single games filed under their generic names. Single games: Groups dedicated to gaming that play one type of game only.

Generic name	Rules	Verb	Single Games
Photo Association	Post an image that relates to the previous image	associate	12
Guess where?	Guess the depicted location	guess	10
Guess what?	Guess the depicted subject	guess	6
ABC	Post an image whose subject starts with letter L, L increases alphabetically	illustrate	4
Flickr-Wikipedia game	Create a fake album cover using Wikipedia and Flickr	create	4
Mosaic game	Create a mosaic using Flickr search on given questions	create	2
Photoshop tennis	Edit an image sequentially	create	2
Visual storytelling	Create a story with images	create	2
I spy	Post an image that depicts a subject spied in the previous image	associate	2
Similar shots	Post an image identical to a previous one	associate	2

4.3 Exploratory behaviour in Flickr group games: Associative games

In this section, we focus on the games identified as associative. Note that the underlying mechanism of associative games can be highly relevant to collection

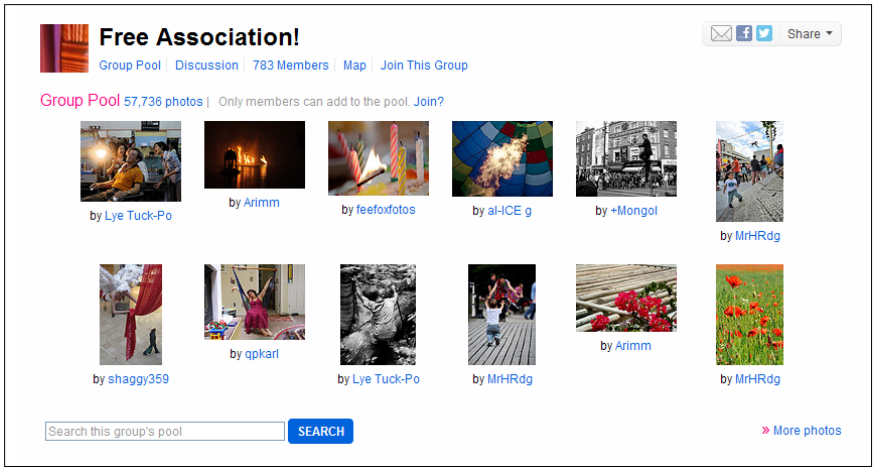


Figure 4.3: A pool-based associative game. Here partial view of the pool of the 'Free Association!' group (group URL: http://www.flickr.com/groups/free_association/). In pool-based games, players post their next move as a new entry in the group pool. Screen captured: 05-08-2012.

exploration: Establishing associations is often related to discovery and knowledge production. Moreover, associative games produce chains of images that are comparable to paths in information space and may be worth exploiting for collection exploration. Towards a closer examination of associative games, we study the game rules and message boards of the groups dedicated to one type of game labelled as associative. Groups dedicated to one type of game often use the entire pool as a game in progress (cf. Figure 4.3). During this investigation, we use collection exploration as a yardstick to organize our observations into three topics of interest, namely chain construction, chain navigation and chain interpretation. Note that this examination is mainly an effort to harvest potentially promising ideas rather than an exhaustive study.

Chain construction: To begin with, let us examine the practices involved in the construction of a chain of images. Images played in a chain are predominantly taken from the player's own photostream. This may be dictated by the use of the pool, although threaded associative games tend to be played similarly. It may also be a reasonable choice against copyright infringement. However, the possibility to encourage players to search or browse for images for the purposes of the game seems to be a missed one. Along a chain, the nature or type of the connection varies according to the focus of the group: Some groups value visual associations (color, shape, composition) while others value links based on the depicted subjects. The mood of a picture, or the emotions it triggers to the player may also com-

prise acceptable links. Non visual elements such as date, place and camera settings may or may not be accepted and so are other conceptual or intellectual links such as word jokes. Overall, players seem to contempt long chains of a very broad subject and a couple of groups explicitly aim for subtle or hard to identify links (cf. 'Tenuous Links' group, group URL: http://www.flickr.com/groups/association/). Note that in the case of subtle links based on depicted content, minute subject details are captured and practically 'zoomed out' in the next transition. Lively discussions on what comprises a successful link are frequent. Players also discuss their strategies for playing the game. Interestingly, players report having taken a picture particularly for the purposes of the game or for future use in the game (cf. Table 4.6). Finally, it should be noted that the majority of image chains are linear: Links are established between two images only, i.e. between the new move and the last image in the pool. Yet, an intriguing exception was found in the 'Matrix Game' group (group URL: http://www.flickr.com/groups/matrixgame/) which requires players to link their move to more than one image in the pool. Such experiments may allow for interesting topologies to emerge.

Chain navigation: Given an image chain, how does one browse or navigate the chain? As explained, dedicated associative games very often turn the entire pool into a chain in progress. This format may pose challenges for the players, who report difficulties in catching up with the last image, but provides more flexibility in accessing the chain. Members of pool-based games seem to be disapproving of long threads with thumbnails as used in threaded games. Pool-based chains are a noticeable example of using gaming as the mechanism to create accessible and interesting subsets of images. This mechanism is apparent in other types of gaming groups too, in particular contest groups that populate their pool with winning images only. However, in the case of associative games, the position of the image and, consequently, its context as provided by its neighbouring images are essential. As such, pool-based chains successfully demonstrate gaming as both a content and a context building mechanism. Moreover, using the pool for the needs of the game can lead to unexpected practical benefits such as the opportunity to use existing widgets for visualization and navigation: The default film strip navigation aid provided by Flickr is a representative example. Another, rather surprising, side effect is reported by Tenuous Links (2008): The default pagination and grid view of the pool resulted in serendipitous associations on the vertical dimension of the game.

Chain interpretation: The use of explanations between moves is a frequent point of discussion among players. Several methods have been proposed to explain a connection between moves, such as adding a comment, tag, note or description text in the corresponding image. Generally speaking, players are reluctant to add permanent elements to their images and seem to prefer comments for explanations. More revealing, however, are the discussions whether an explanation should be provided at all. Opinions on this topic are divided and may depend of the focus of the group, e.g. visual, conceptual or subtle links. Explanations can assist in the case of difficult links and may provide a prevention mechanism against random posting (not connected images are deleted in most of the groups). Yet, in some cases, players seem to value the challenge of reconstructing an association and they perceive explanations as limiting to the imagination (cf. Table 4.6). Surprisingly, players report that they appreciate coming up with their own association, even if it is not the intended one. In our view, this may be a first step towards turning these chains into meaningful narratives.

4.4 Conclusion

This study attempts to crystallize aspects of gaming activity in Flickr groups. The work is indented as an exploratory study along the lines of 'gamification' for collection exploration; automation was, therefore, not a priority. While our study is certainly subject to human bias, we trust that it provides a useful scouting of the Flickr ecosystem: A good understanding of the types of gaming activity and games encountered as well as of the vocabulary involved can be beneficial towards more automated investigations. A more robust system for group or game classification should be visible but a better way to gather a representative sample of groups from the Flickr database remains an issue. The ambiguity of the term 'game' not only impairs the retrieval of relevant results but also hinders the filtering process. In our case, it is plausible that groups excluded as irrelevant upon their description text do play threaded games as secondary activity as well.

Stvilia and Jörgensen (2007) discuss Flickr groups as community spaces providing opportunities for learning, for feedback and for entertainment via games and tournaments. Furthermore, the authors relate games to 'active' viewing of images and note that games can be used for "building context and telling a story of a place or a person". Such an observation is particularly relevant to our research on appropriating games for playful and exploratory interactions with images. During our study, we tried to better understand the processes and conditions for such an effect to occur. In other words, we questioned how or when image games may

Table 4.6: Relevant quotes extracted from description texts and discussions held in the message boards of single game, associative groups. Data accessed: 19-11-2010.

Topic of interest	Quotation
Deliberately shooting a move	"Crossed a line yesterday by taking a photo just for Snap!" (source: http://www.flickr.com/groups/snap_game/discuss/36652/) "I haven't taken a picture for a specific link, but I do take pictures of things that I wouldn't ordinarily photograph because it might make a good link someday" "I haven't taken a picture for a specific link, but I have posted pictures to Flickr for a specific Tenuous Link." (source: http://www.flickr.com/groups/association/discuss/72157603673979260/)
Threads vs pools	"I definitely want to keep the links in the pool - I think it's easier to see the latest photos at a glance this way, rather than scrolling down a thread", "I am against the putting photos in threads. Takes too much bandwidth" (source: http://www.flickr.com/groups/association/discuss/72157594512516387)
Comments vs permanent elements	"I agree that comments are a better form. There's more space to elucidate the association, and the comments can add to your tally for explore. Some people have hundreds of tags, so the comments would then be, at least, at the bottom and easy to find.", "I'd prefer comments, too. I'm kind of picky about my tags" (source: http://www.flickr.com/groups/gameofphotoassociation/discuss/72057594097646962/) "I always delete notes that are added to my photos, I find them distracting." (source: http://www.flickr.com/groups/free_association/discuss/72157613635786863/)
Explanation vs no explanation	"Sometimes people have questioned what someone else's association is, and the discussion revealed all kinds of possible associations: different ones to different eyes", "I want to put my own interpretation on the association. I would rather not be told" (source: http://www.flickr.com/groups/free_association/discuss/72157613635786863/) "I think if you had to explain the link there would be no fun in this game, either when you post a picture or when you ask yourself what link another poster had in mind" (source: http://www.flickr.com/groups/snap_game/discuss/72057594069503455/)

support building context and, particularly, how game rules and game mechanics may affect this process. A significant observation we made is that pool-based associative games provide the means to populate a pool while indeed deliberately creating a neighbouring context for each image. In fact, the example provided by Stvilia and Jörgensen (2007) to illustrate their remark on context and storytelling turns out to be what we would call a pool-based associative game. In associative games, context building is facilitated by both the rules (associate images in a linear fashion) and the chosen format and available visualization (group pool). Further research is required in order to better understand the storytelling aspects of Flickr games. In particular, the function of text as a gaming element should be more carefully examined.

If games are to support a more exploratory interaction with an image collection, associative games are a considerable genre to implement. Associative games provide a mechanism to construct potentially meaningful chains of images with meaning being captured in the connections across images instead of the content or metadata of a single image. Such 'interrelations' are user-generated and may have a high degree of serendipity: Players respond to stimuli (i.e. previous image) in a creative way and reconsider their own collections in relation to the pending image. Eventually, these trails of player activity should be accessible to traverse by both players and future viewers. To that end, efficient visualizations and usable navigation aids are of particular importance. Finally, it is worth noticing that chains produced via associative games differ from thematically defined galleries as they require the viewer to decode the connection between two moves. This may call for a more active look into the images in question and can potentially result in even more associations being made. A surprising observation we made is that players often value ambiguity and enjoy the challenge to reconstruct an association. Such engagement with devising or reconstructing associations is extremely relevant in the context of collection exploration, particularly while traversing interconnected information points.

Online, community-driven games such as the ones identified in the Flickr ecosystem could be applicable to other types of image collections, i.e. scientific image databases, providing that the necessary infrastructure and an active online community of users are in place. More importantly, this study allows us to contemplate on alternative formats of gaming with images. We note that Flickr games may not always comply to a strict definition of the term 'game', although they are clearly perceived as games by their initiators and participants. Considering activities without an explicit winning condition introduces new directions for play and playfulness with images. Furthermore, we observe that ambiguity is received

positively and can actually serve as a source of play. Employing ambiguity as a design principle is another exciting direction that playing with images can head in. Note that the playful potential of ambiguity has been highlighted by Gaver (2002); Gaver et al. (2003), whose concept of 'ludic interfaces' (Gaver, 2002) emphasizes open-ended, interpretative and non-task oriented ways to engage with technology. The suggested role of ambiguity in 'ludic interfaces' corresponds with our observations on ambiguity as a source of play; in a sense, ambiguity can be playful for it introduces opportunities for new usages and interpretations.

Chapter 5

Playing with images 2: Storytelling as playful interaction

Based on:

A. Kallergi and F. J. Verbeek. Storytelling as playful exploration of biological image data: Reviewing a candidate interaction paradigm. In Proceedings of the IADIS International Conference Interfaces and Human Computer Interaction 2012, pages 35-42, 2012

Abstract: This chapter examines the applicability of storytelling as a way to playfully interact with scientific image data. Arguing that scientific practice can benefit from a moment of openness and playfulness, we propose a story-based interaction with image data as a means to ignite playful and creative responses to scientific images. By means of a literature review, preliminary user studies and the implementation of a concrete storytelling artefact, we attempt to better understand the potential, relevant aspects and specific challenges of storytelling with scientific images. LABBOOK, our current implementation, is an instance of a storytelling artefact that is a digital collaborative storytelling game for biologists and their images. The game should be understood as a platform for storytelling and social exchange. By confronting the players with the challenges of story composition, LABBOOK has demonstrated a capacity of storytelling to probe an active look into the images involved.

5.1 Introduction

In this chapter, we examine the applicability of storytelling as a way to playfully interact with image data from the life sciences. The reader of this thesis should, by now, be familiar with our interest in interaction paradigms along the lines of playfulness, exploration and creativity. Storytelling with images is such a candidate interaction paradigm we investigate. Partially motivated by the finding of our Flickr study (cf. chapter 4), our interest in storytelling as a way to play with images marks a shift from rule-based forms of play. In chapter 3, we considered playing as gaming and exploited the formal rule structure of a game. In this chapter, on the other hand, we adopt a less rigid understanding of playing as creating and exploit the relevant qualities of stories and storytelling. Moreover, while chapter 3 focused on communicating existing connections between images, this chapter is mainly concerned with the articulation of new associations regarding scientific images.

Biology is a science typically oriented around visual clues. Much of contemporary biological research is based on the production, inspection and analysis of image data as produced by various experiment designs and various imaging systems. Obviously, image data are used in scientific discourse and publication as persuasion and communication means to support and better demonstrate a finding. Nevertheless, the life cycle of a scientific image is much richer and far more dynamic. For instance, images as preliminary or intermediate findings can be used to guide and refine research choices. Images as snapshots of ongoing research must be discussed and reflected upon for further decisions to be made; conversation and references to other images are two mechanisms that inform and transform one's response to image data. As repeatedly argued throughout this thesis, managing one's research by incorporating observations from image data may benefit from an open-minded and exploratory attitude of the researcher. In search of new ideas, challenging questions or simply insightful observations, it is often useful to re-consider and re-interpret one's own data under the light of other data or under the light of new associations, non-obvious and unexpected ones included.

This chapter investigates storytelling as a means to play with scientific images in ways that could potentially stimulate creative responses to image data. We are particularly motivated by the role of associations as a way to process and synthesize information and the role of imagination as a way to articulate potentially useful ideas, toy with possibilities and even create associations where there appears to be none. A story-based interaction with scientific images may be a valid

strategy to ignite similar processes: By creating opportunities for storytelling, we hope to create opportunities for a great deal of re-consideration, re-interpretation, imagination and filling-in of gaps to be at work. Potentially, storytelling and the processes we associate with it can be exercised in a shared or social context. The work presented in this chapter manifests our increasing attention to the social aspects of scientific creativity. While the cognitive processes relevant to scientific creativity are interesting, one should remain attentive to the fact that scientific creativity owns a lot to social exchange and collaboration. Our storytelling paradigm expands to address both storytelling with other images as a process of synthesis and storytelling together with other researchers as a process of conversation.

The structure of this chapter is as follows: Section 5.2 summarizes interdisciplinary ideas and practices regarding storytelling with images. Utilitarian usages of storytelling are many and accomplished and have motivated our interest in a story-based interaction with scientific images. A series of preliminary user studies towards a storytelling game for scientific images is described in section 5.3; these studies inform both our understanding of storytelling with scientific images and our design trajectory towards a concrete product. Section 5.4 presents LABBOOK, our current implementation of a collaborative storytelling game for biologists. Results from the evaluation of the current product are discussed in section 5.5, while section 5.6 presents our conclusions from our involvement in (designing for) storytelling with images from the life sciences.

5.2 Motivation

This section discusses relevant aspects and qualities of stories and storytelling as drawn from literature and from various products and practices employing storytelling with images. Essentially, storytelling involves a process of articulation and of synthesis which we find particularly valuable. In addition, its considerable playful and social dimensions are of equal relevance.

5.2.1 Of stories and storytelling: A few definitions

First of all, what is a story? Defined casually, a story is an account of events; these events can be “either true or false” (Polkinghorne, 1988, chapter II). Everyone’s got a story to tell, and it need not be one of a literary value. Stories and narratives can be treated as either synonym or distinct terms depending on whether a story is understood as distinct from its rendering (Abbott, 2007). We will use the term ‘story’ and ‘narrative’ interchangeably, with story being the account of a sequence

of events rather than only the sequence of events accounted. This definition is closer to an everyday understanding of the term 'story' but it still allows us to consult the extensive field of narratology, i.e. the study of narratives. However, here be dragons! The field of narratology is a fearsome one, perturbed by its own definition wars, including ones on the definition of narrative. An account of a sequence of events may not always demonstrate a satisfying degree of 'narrativity'; a typical example given is the chronicle.

The focus of this work is on storytelling that includes and initiates from images. To be more accurate, it is about story-making rather than story-telling. For the remainder of this chapter, the term 'storytelling' will refer to the telling of a story that is actively generated by the storyteller, rather than the reciting of an existing story. Story-making need not be mediated by an artefact, but there exists a long tradition of 'user-generated' stories, i.e. stories unfolded or produced by the user's interaction with a tool or platform. Numerous environments or strategies have been attributed a capacity to support or engage a reader or player into the production of narratives: Hypertext fiction, interactive storytelling and videogames, mainly adventure and role-playing games, are a few typical examples, all distinct in their mechanics and aesthetics and yet alike in their ascribed potential to transform 'traditional' narratives. From a cybertext theory (Aarseth, 1997) perspective, user-generated stories will involve 'non-trivial effort' and interaction with a mechanism/algorithm operating on a set of building tokens. We are aware of this tradition of interactive and playable stories and acknowledge the impact of technologies and interactivity on the way stories emerge. Technically, the use of small units of information to be assembled by the user in a meaningful storyline is a theme we adhere to. However, we are less interested in the trails of the user as an output (cf. hypertext) or the choices of the player on particular forking or decision points (cf. interactive storytelling).

5.2.2 Why stories?

There is a substantial tradition on storytelling as a means to understanding. Firstly, stories have been long acknowledged as carriers of information and as a means to transmit know-how, beliefs and values across generations. Their cultural significance aside, stories are powerful communication tools. This applies to the domain of science as well: As most science communicators would confirm, stories about famous scientists, significant scientific discoveries and even complex scientific phenomena are powerful and engaging educational aids. Avraamidou and Osborne (2009) provide an extensive overview of the applicability of narratives

for science education and science communication. Clearly, stories help transmit a message and make a speaker easier understood. But can a story make a speaker easier understood to the speaker herself? In other words, can the composition of a story contribute to understanding? Several practices would support the case as stories have been frequently used to either elicit or organize information. Consider as an example the use of narratives in social science research: Stories have been repeatedly used as the means for human subjects to articulate about their experiences. What is more, narrative inquiry as a methodology engages with stories as both the subject and the means of the inquiry. That is to say, stories are either the collected material to be analysed or a medium for the researcher to make sense out of her own observations (Polkinghorne, 1988; Pinnegar and Daynes, 2007, chapter VII). In a similar fashion, storytelling has been applied for knowledge management in organizations, e.g. as a way to verbalize tacit knowledge about a task or about the organization (Hannabuss, 2000; Rhodes and Brown, 2005). Similar practices are to be found in the field of HCI, with storytelling being used as a tool for brainstorming or user-centred research. In all of the above cases, storytelling is employed to stimulate and facilitate the articulation of useful information and knowledge that would otherwise remain implicit.

Storytelling seems to be a natural and comfortable way for humans to cope with information and complexity. The idea of a narrative way of thinking which qualifies as a distinct mode of reasoning was pioneered by Bruner (1986) and Polkinghorne (1988). The exact nature of narrative knowing and narrative reasoning as well as the exact relation of narrative reasoning to paradigmatic (or logico-scientific) mode of reasoning are discussions we will refrain from. However, we find it fascinating that the way we process stories requires a particular way of connectivity between parts. Firstly, it requires some connectivity: Parts of a story become meaningful because they contribute to a plot. To quote Polkinghorne (1988, chapter II), “narrative ordering makes individual events comprehensible by identifying the whole to which they contribute”. Secondly, the connectivity involved is of peculiar nature. The causal relation between parts is by far not necessary, but it is still sufficient. As Worth (2005) summarizes, “narrative lines of reasoning do not generally prove anything, but they do show how something might have come to be the case”. In a way, what makes stories particularly attractive is exactly the need to devise or imagine explanations that impose coherence over discrete items.

For the sake of completeness, a word of mention is due to the types of texts or stories specifically produced by scientists. As already mentioned, narrative inquiry and science communication are straightforward examples of the use of

stories in scientific practice. At the same time, scientists produce a variety of written texts which may or may not be understood as stories. The various scientific writing 'genres', e.g. the research article or the conference presentation, are definitely worth analysing in terms of language and rhetoric devices employed. Such purely argumentative scientific texts have been in times examined under the lens of traditional narratives (Dubois, 1992; Sheehan and Rode, 1999; de Waard, 2010). Then again, debates over the narrativity of scientific texts are irrelevant to our purposes as we are motivated by the processes of verbalizing, composing and articulating, not by the nature of the output text. As regards the act and process of writing, it is useful to observe that scientific writing can be integral to scientific inquiry as opposed to ensuing it. Holmes (1987) studied manuscripts of prominent scientific figures to suggest that the act of writing may have played an active role in the conduction of research. Specifically, the need to formulate one's research into a legible and coherent whole for an informed and critical audience may help the researcher identify gaps, synthesize ideas and conceive new experiments. Naturally, we wonder if verbal articulation for the sake of storytelling with research material can have a similar impact.

5.2.3 Related work

In Kallergi and Verbeek (2012), we review a number of products and practices relevant for the domain of HCI that involve storytelling with images. The review discusses a number of applications, from card games to smartphone applications, and a number of practices, from design and brainstorming methodologies to interface metaphors in personal photoware. Generally speaking, storytelling with images was found to be discussed and employed as:

- creative play
- a means to probe articulation, of both new and existing knowledge
- a means to impose structure

When used as an organization metaphor in interfaces, storytelling is generally employed to either facilitate image sharing or to facilitate image retrieval. All things considered, storytelling allows participants to make explicit, to make coherent, to play, to share, to organize. Such well-established functions of storytelling can be of relevance for a playful and exploratory interaction with scientific image data. Note that storytelling with images spans across a variety of applications, from analogue games to video games to story editors, and a variety of story construction methods, with or without a narrative theory backdrop and with or without gener-

ative capacities. These features mark a valid design space of potential artefacts for storytelling with scientific images.

Closely related to our interest in a story-based interaction with scientific data is the work of Kuchinsky et al. (2002). The authors propose a biological storytelling metaphor as a means to organize various data about biological entities (genes, proteins etc.). We endorse the authors' propositions on the relevance of storytelling for scientific reasoning and practice. Their notion of synthesis as a necessary part of hypothesis formulation greatly corresponds to our notion of a synthesis via the establishment of associations. However, their work does not consider the particularities of image data and of image-based storytelling, which are the focal point of our research.

5.3 Preliminary user studies

We have been particularly motivated by the qualities of storytelling and the potential we perceive for igniting creative responses to image data. Yet, despite the widespread applications of storytelling with images, storytelling with scientific images is a novel and somehow unconventional practice for researchers in the life sciences. How would our target users respond to the practice of storytelling with research images and what features should a storytelling artefact for research images support? To tackle these issues, we conducted two preliminary users studies as further documented in this section. We consider these studies to be both a means to an end, i.e. a well-received product, and a research methodology that enables us to shed some light on the topic of storytelling with scientific images.

5.3.1 Probing stories: Storytelling with image blocks

Why we did it

In a preliminary and rather exploratory study, we invited users to share and create stories around their research image material. Our intention was to simply observe the type of talk around and about images and to test a few aids that could potentially facilitate story construction. If storytelling with research images is an unfamiliar practice for researchers, what kind of tools, metaphors and visual or lexical clues can we supply to probe storytelling? As a start, noticing that the comics idiom has been previously applied for sharing or authoring personal photos, we introduced a comic strip metaphor. Our hypothesis was that the comics aesthetic may set the tone for more playful expressions and that a limited

structure such as the comic strip may facilitate users to express their stories in episodes.

How we did it

Three researchers (3 bio-informaticians/ 2 male, 1 female) working with images from the life sciences were invited for individual interviews. Each interviewee was provided with a set of image blocks and utility blocks. Image blocks (cf. Figure 5.1) were derived from the participant's latest conference presentation. Utility blocks (cf. Figure 5.2) consisted of speech balloons, captions and character blocks. The subjects were asked to produce two distinct images sequences, namely a synthesis of their images into a story and a three panel comic strip. All sessions were video-recorded (137 minutes of footage).

Highlights

When asked to tell a story with their images, all subjects reconstructed a 'scaled-down' version of their presentations. The result is a diagrammatic representation of the research addressed in each presentation. When asked to produce a 3-panel strip, responses varied. One subject produced an exceptionally complete and valid comic strip: The strip includes time progression, conflict and resolution elements, two characters and dialogue. The other two subjects, both involved in image processing, used the 3 panels as 3 distinct processing steps, adding connecting lines between the panels to represent input or output. Simply put, these subjects turned the comic strip into a diagram instead of a narrative sequence. However, when asked to re-describe the same sequence starting with the phrase 'Once upon a time', both subjects unmistakeably switched to a storytelling tone. It should be mentioned that both researchers were surprised at first and actually laughed at the introduction of the sentence. Yet, they both continued the phrase by immediately introducing a character. One subject introduced a hero/protagonist, namely a researcher who produces and analyses images. The other subject 'personified' the biological phenomenon under study ("Once upon a time, there was focal adhesion living together with a cell").

What we have learned

We believe that the challenge in (designing for) storytelling with scientific images would be the switch to a narrative tone or mindset. Note that all subjects eventually narrated a story around their images when properly prompted to. In our experience, chiché phrases and archetypical characters were of considerable help

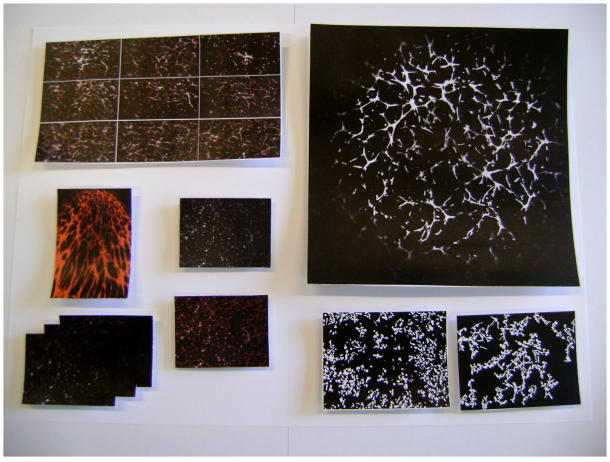


Figure 5.1: Image blocks (partial view) as derived from the subject's conference presentation.



Figure 5.2: Utility blocks, including speech balloons (speech, thought and scream balloons), captions and character blocks.

while the comic metaphor was not as helpful as expected. Interestingly, subjects were aware of their difficulty to treat their images outside of their regular framework. One subject remarked that researchers are always too much 'into' their images and further suggested introducing a few irrelevant images in the set in order to 'break' this fixation. Another subject commented on having presented the corresponding research topic 'dozens of times' and further suggested conducting sessions with researchers in earlier stages of their research. With these observations in mind, we concluded that our storytelling artefact should provide substantial support towards setting the right tone or mindset for storytelling.

Glimpse on the potential of storytelling with scientific images

What can this exploratory study suggest about the potential value of storytelling with image data from the life sciences? As expected, stories can work well as means of communication. Two of the subjects associated a storytelling mindset to explaining their research to (non-technical) listeners. As this study was based on existing presentation material, it is likely that our subjects perceived storytelling as an alternative delivery channel of an already worked-out story rather than as a productive synthesis of their material. An unexpected but easily explained result was the capacity of stories to capture the researchers' personal experiences and the social dynamics of scientific practice. In particular, two of the subjects included collaboration with other scientists in their stories and further articulated about the challenges of collaboration.

5.3.2 Playtesting stories: Storytelling with a card game

Why we did it

For our next step, we encapsulated the act of storytelling into a game. The primary aim of our game would be to 'loosen up' the storyteller, a requirement identified in subsection 5.3.1. Narrative aids such as cliché phrases and characters should steer the player towards a more narrative tone, while gaming elements should poke a more playful attitude. In addition, we decided on a multiplayer game mode as a means to probe both storytelling and social interaction. Motivated also by other storytelling methodologies that utilize cards, we formulated the act of storytelling into a card game. However, we refrained for designing a finalized game concept and, instead, invited our players to collectively devise game rules.

How we did it

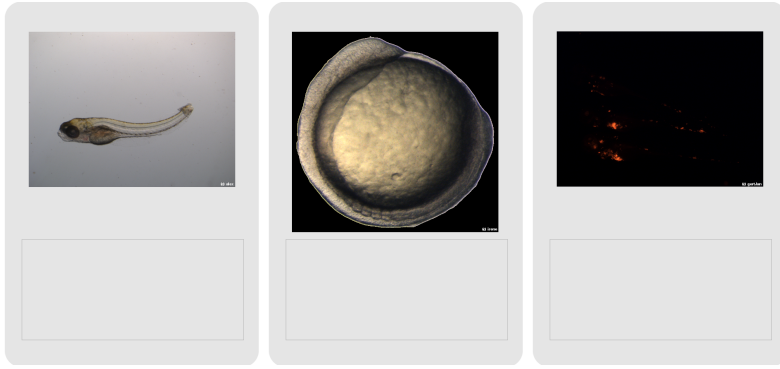
Three researchers (2 bio-informaticians, 1 biologist/ 2 male, 1 female) were invited for a group session. Prior to the session, subjects were asked to submit a number of images (minimum 5 per person) from their current research. We created a deck of cards that included image cards out of the participants' images (cf. Figure 5.3a) and various utility cards (cf. Figure 5.3b) such as help cards with characters, genre cards with common literary genres, start cards with opening lines and end cards with closing lines. The entire set of cards used in the session can be found in appendix B. After a short introduction, the players were provided with the deck of cards and a rudimentary set of rules (deal a hand, play a card, try to finish your cards first). Their task was to comment upon the rules, resolve ambiguities, identify flaws and propose modifications. The session was audio-recorded (74 minutes of audio). Players were also asked to fill in a questionnaire about both the initial and modified gameplay.

Highlights

It was immediately apparent that the initial game rules were obviously under-developed. Specifically, the first player to start was also the first one to win. Our players got occupied with this flaw and devised an accumulating number of restrictions that would limit a player from playing her card. However, it was particularly interesting to see that the players reported no difficulties in playing their cards; on the contrary, they found it particularly easy to add their card to the ongoing story. The players themselves attributed this ease to the similarity of their images. For the record, the players did not manage to propose a set of rules that would resolve the identified issue. However, many of their suggestions were incorporated in the next incarnation of our game concept.

What we have learned

We have been particularly motivated by the fluency and ease of our participants during story construction. That said, we admit we have no sufficient data to tell which factors contributed to this fluency. It could be the personality of the players, the card game format, the new narrative elements in the utility cards, the playfulness embodied in the cards themselves, the presence and input of other players or the cookies on the table. Generally speaking, the character and genre cards were well-received with the latter being assigned a progressively more prominent role in the game. What is more, we observed that players repeatedly



(a) Examples of image cards. The provided deck included image cards out of research images submitted by the players prior to the play session. In the session, players were asked to annotate the cards and incorporate the annotations in the game as they deemed appropriate.



(b) Examples of utility cards. The provided deck included help cards with characters, genre cards with common literary genres, start cards with opening lines and end cards with closing lines.

Figure 5.3: Examples of cards used in play session. The complete set of cards can be found in appendix B.

motivated and complemented each other. Other players can, in fact, be a valuable catalyst in probing storytelling.

We have been attentive to what we believe to be a tension between a competitive game mode and a storytelling mechanic. A resolution such as finishing your hand first was hard to implement in a fair manner and so was a clear criterion for accepting or rejecting a move. Players soon fell back on a scoring mechanism and a winning condition based on accumulation of points after several rounds. Nonetheless, accumulating restrictions in playing the next card had a negative impact on the pace of the story with players being noticeably slowed down in composing their moves. We suspect that storytelling is better experienced as a loose playful activity, and it may actually not require a winning or scoring condition. To some extent, this observation corresponds with our findings in chapter 4: Flickr image-based games, such as the ones based on building chains of images by associations, repeatedly lack a winning or scoring condition.

Glimpse on the potential of storytelling with scientific images

The stories produced were strikingly rich in their imaginative power. Our players would easily introduce zebrafish with super powers and zebrafish jumping free out of their wells. There were also ready to turn fluorescence signals into galaxies and zebrafish embryos into planets; in the words of one of our players, they 'fantasized' about their images. A very promising observation was found in the capacity of our players to appropriate visual details for the sake of story composition. This attention to visual details goes beyond obvious elements (e.g. dark eyes) to minute or irrelevant details in the image (e.g. imaging artifacts). Associations across images were also observed: A bright-field image of fish followed by a fluorescence image of fish was explained as the zebrafish obtaining infrared vision while differences in the orientation of the imaged fish were highlighted ("the fish turned around..."). The players seemed to enjoy the stories they produced while positive attitudes towards the opportunity to be exposed to other researchers' images were off-the-record expressed.

5.4 LABBOOK, the collaborative storytelling game

This section introduces LABBOOK, our current implementation of a digital, collaborative storytelling game for images in the life sciences. The game should be understood as a platform that creates opportunities for storytelling in a shared and social context. LABBOOK confronts the players with the challenge of story

composition and invites them to imagine associations, re-consider their own and one another's images and participate in social exchange. The game employs digital images as dictated by practical needs and a reasonable approach to data management.

5.4.1 Concept design

Despite lacking well-defined rules, the paper-based card game described in section 5.3.2 seemed to perfectly facilitate the mood and attitude we were after. Naturally, we question: Can we mitigate our card game to the digital domain without sacrificing its playfulness and its affordance? Which are the distinctive aspects of the experience that we should strive to maintain and which modes of play would permit us to do so? We decided that the game should remain multiplayer, it should maintain narrative aids in the form of utility cards and that, while being digital, it should provide some elements of physical interaction.

In putting forth our requirements for the next game concept, use case scenarios were of particular help. Clearly, the major aim of our game is to stimulate collaborative storytelling. But how and under which circumstances do we envision our game to be played? Considering the workflow and actual routines of a practising scientist, how do we create opportunities for storytelling that are not artificial and do no introduce hassle for the researchers? Providing realistic answers to these questions is crucial for the adoption of our product. With these in mind, we provide the following use case scenarios:

1. The coffee table scenario: Colleagues of the same research group use the game as a pastime activity during coffee breaks. They play a couple of rounds with one another's images while at the coffee room of the institute. The game may be laying around at the shared facilities or be owned by one of the group members.
2. The ice breaker scenario: Collaborators in an interdisciplinary project use the game as an introductory activity during a project meeting. They play a couple of rounds with one another's images to get acquainted to the work or research interests of each collaborating party.

Note that both of the above mentioned scenarios expect the players to be co-located.

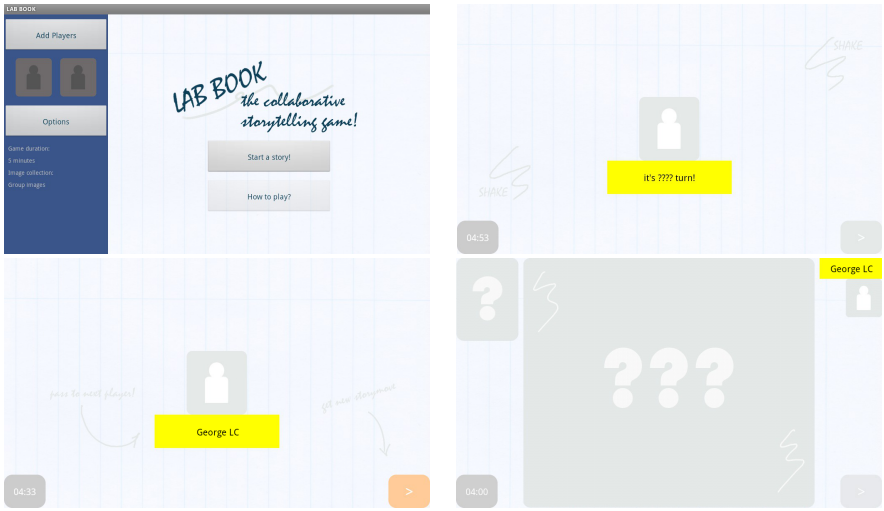


Figure 5.4: Screenshots of LABBOOK, the game. Players play in random order and the new next player is drawn by shaking the tablet. Stories unfold storymove by storymove and the new storymove is drawn by shaking the tablet.

5.4.2 The game

LABBOOK (cf. Figure 5.4) is a collaborative storytelling game for biologists and their images. It is played by a group of players on a tablet computer shared among the players. The aim of the game is to collectively construct a story around a collection of research images and within a set time limit. Stories unfold image by image with the players taking turns in the same story: The player whose turn is due draws the next image/storymove that she attaches with her narration to the ongoing story. One storymove (cf. Figure 5.5) is a combination of a random image from the image set and a random utility card. The progression of the story is linear: A new move connects to the previous move and new moves are drawn by shaking the tablet. The sequence of the players is arbitrary: Players play in random order instead of in turns and the new next player is drawn by shaking the tablet. The story ends when the time is up with a random closing line. The player's narration is automatically audio-recorded and can be played back at the end of the game. There is no (extrinsic) reward other than enjoying the process, the company and the generated story.

Controls and design choices

At the core of our game is collaborative storytelling with scientific images. Thus, the fundamental elements of our game are the players and their images. However,



Figure 5.5: One storymove is a combination of a random image from the image set and a random utility card. The player whose turn is due (highlighted at the top right corner) attaches the storymove to the ongoing story using hints from both the image and the utility card. Utility cards provide various suggestions including characters, places, literary genres or annotation terms from the image collection.

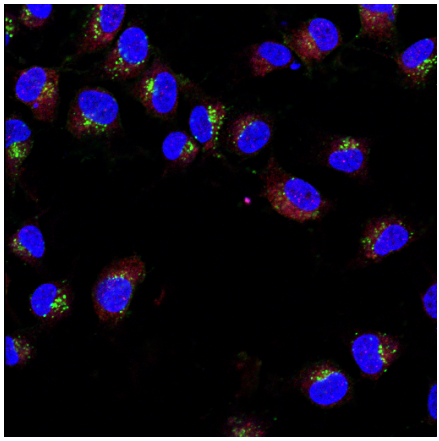
another essential component is the platform the game is played on. The tablet computer entered our design as a solution to our requirements for a shared, collaborative and fluent story development: It provides us with a shared space and a shared story timeline similar to the ones supported by a card game. Then again, having a tablet at our disposal introduced new opportunities for game design. Mitigating the game to the digital domain offers functionalities that were not available to us beforehand while the hardware itself, i.e. a portable tablet with a touchscreen, microphone, speakers and accelerometer, supports additional interactions to be further exploited. To begin with, the tablet's interface allowed us to introduced a shake control which we hope to aspire a feeling of chance and to highlight the randomness involved in each storymove. Secondly, the size and mobility of the display, as opposed to a tabletop, could potentially increase physical interaction with or around the display; we attempt to capitalize on such an opportunity by introducing the random play order. Drawing one move at a time instead of being dealt a hand and the combination of one utility and one image card into a single storymove were suggestions brainstormed by our test players (cf. section 5.3.2). LABBOOK is developed in Android 2.3.3 and deployed on a Blackberry Playbook 7' tablet.

5.5 Results

5.5.1 User evaluation

LABBOOK was evaluated by four novice users (4 life science students/ 2 male, 2 female). The major aim of this evaluation was to test our game design choices for playability. The players were asked to play the game first in pairs (2 groups) and then in a group of four (1 group). The game was played with a set of 15 images out of two research projects previously presented to the players (cf. Figure 5.6). That is to say, the users had prior exposure to the images and a thorough introduction to the research topics involved but were not the ones producing or researching the images involved. The sessions were audio-recorded (51 minutes of audio). Players were encouraged to play the game in their native language, i.e. Dutch. Play sessions were followed by interviews and players were also asked to fill in a questionnaire at the end of each 2-player session.

As reported by the players, the game rules and in-game interface were straightforward. Players had no difficulties in figuring out what to do next (cf. Table 5.1) and they quickly resolve the shake control and random player turn. Interestingly, one player concluded that the game is very easy to play because “there are actually no rules”. While LABBOOK has indeed no rules on how to make a move or on how to win, it has of course a structure and logic in its progression; this logic was immediately internalized by the players. Regarding some of our game design choices, the random turns rule was once reported as contributing most to the enjoyment of the game. When playing in pairs, a very long sequence of moves by the same player was frustrating to the player involved but amusing to the other. Nevertheless, a long sequence of moves should not be much of an issue when more players are involved. Responses about the shake control were indirectly related to the random turns rule: Generally speaking, the shake control was found to be playful but too many shakes in a row by the same player were reported to “disturb the storytelling a lot”. Mobility of the tablet was not an issue but the tablet’s role as a shared surface is disputable. During the 2-player session, players would frequently interfere/participate in each other’s move. This behaviour was not observed during the 4-player session. In fact, one player commented on the missed opportunity to look at the image being narrated during the 4-player session. The issue of visual access definitely requires our further attention: Potential solutions may span from introducing simple interface hints to adopting alternative technologies.



(a) EGFR-induced breast cancer cells visualized with a confocal laser microscope. Three channels are captured: A red channel (Cy3) containing P-ERK expression staining, a green channel (Alexa-488) containing EGFR expression staining and a blue channel (Hoechst #33258) containing a nuclear staining. Image courtesy of Division of Toxicology, Leiden Amsterdam Centre for Drug Research (LACDR).



(b) Bright field image containing a zebrafish larva imaged with a Leica DC500 microscope. Image courtesy of Department of Molecular Cell Biology, Institute of Biology Leiden (IBL).

Figure 5.6: Examples of research images used in user evaluation.

When it comes to story construction, we were pleased to observe that the aids incorporated in LABBOOK were overall appreciated. Utility cards were well-noticed with players frequently starting their sentences with the utility card text. One player particularly valued the opening line mentioning that it removes the burden "to create a good beginning". Most noticeably, after the 4-player session, all players highly appreciated the input of other players as a source of inspiration (cf. Table 5.1). All in all, LABBOOK seems to successfully integrate playful elements, narrative aids and the multiplayer mode. Then again, our players were of the opinion that it is the image set that governs story construction. All players asked for more diverse images in the game; they were fatigued by the reoccurring images feeling unable to come up with new ideas. This fatigue was reported not only after multiple sessions but already within a single session: The reappearance of the same type of images in the same story was found to hinder story construction. Interestingly, similar images have been found to be both an aid (easy to connect in a coherent way) and a hindrance (lack of new ideas). Some middle ground should of course be attainable. For instance, one of our players suggested the possibility to select a theme in the beginning of the game, a suggestion that may allow us to balance variation and coherence. Variation in the image set is a parameter we need to further consider and so are the total number of images included and the variation between storymoves. Note that image annotations could be exploited to calibrate variation: By means of annotations, we can potentially guarantee either sufficient similarity or sufficient variation within the image set and/or between two storymoves. Eventually, images will be supplied by the players themselves but we can always manipulate the search space of available storymoves.

5.5.2 Impact

The stories produced with LABBOOK further confirm our earlier observations on the capacity of storytelling to engage players with visual details in the images. Once again, players appropriate visual details for the sake of story composition; as a matter of fact, they are very attentive to the image content. Green, red and pink specks in the image, the orientation of the fish and the positioning of the cells are repeatedly captured in the players' narration. The players' capacity of finding and utilizing patterns in the images is impressive. For example, players very often group cells together and propose that (groups of) cells move away or towards each other (cf. Table 5.2). Players were also able to make associations between subsequent images. For example, they often include in their narration

Table 5.1: Relevant quotes extracted from play sessions and questionnaires (player id indicated as A# for the first pair and B# for the second pair)

topic	quotes
support: interface	"sometimes when you are in a game or something you think what do I need to do now? this explains itself" [B1], "there shouldn't be much more in the screen because you are thinking about what you are going to say and shouldn't be distracted by more things" [B2]
support: other players	" I think it's nicer to play with 4 people instead of 2 [...] more ideas, different people know more things, so you can just adapt to someone else's story when you don't know what to say" [B1], "more different, more inspiration, we have different points of view, although it got less because we got it a couple of times" [A2]
support: image set	"There has to be a bigger variation in the pictures, I think that's also something that really matters, because right now they are all the same, so we can't talk for hours about it any more..." [A2], "[B2] It is nice if there are different pictures ... [B1] you make a story and then the same pictures come back so you can't continue with your story [B2] but it is a good thing that sometime the same pictures come back..." [B1, B2]
impact: potential use	"it's more like a game for people who want to be creative, because you need to be creative to keep coming up with something new" [B1], "maybe it's a good exercise when you are afraid to talk spontaneous in a group, and you just pass on the tablet and everybody says something, it gives you a subject to talk about" [B2]

the increase or decrease in the number of cells or fish depicted; multiplication, death and joining/being joined by other members of the same type were some reoccurring themes. Another frequently used strategy was zooming in or out in content when images of fish were followed by images of cells and vice versa (cf. Table 5.2). Appropriating visual details within a single image and employing the differences between two images are practices repeatedly observed among tests and groups. Hence, we believe we can safely suggest that players do resort to a more active look into images when confronted with the challenges of story composition.

Table 5.2: Story fragments extracted from audio recordings translated from Dutch (story id indicated as A for the first pair, B for the second pair and AB_# for the joined group)

topic	fragment
patterns: grouping, movement	"the cells were afraid of each other and flew to the other side" [AB_1] "they all went off to different directions" [AB_2] "then they all decided to go line dancing" [A]
transitions: zoom in/ out	"the computer analyst saw in the zebrafish [...] that a cluster emerged" [A] "the tragedy was that the fish had only two cells" [B] "and the cells were actually one big zebrafish..." [AB_1]

A new aspect observed during the LABBOOK game sessions was the employment of prior biological knowledge in order to compose a move. As expected, the players often referred to the knowledge they had acquired on the projects represented in the image set. It should be repeated here that our players were prior and independently of the game sessions exposed to the research of two of our colleagues who contributed the images. Naturally, the players often reflected on the newly introduced research topics and workflows and were able to identify and utilize for their narration the correct content of the image. What was, though, surprising was that the players made use of prior knowledge also in the *absence* of image or help content. More specifically, one player talked about "jellyfish being worried because they lacked vesicles and clusters"; this was indeed the case in the cells depicted. We argue that it would be highly unlikely to compose such a move without relying to one's prior biological knowledge. To put it differently, a non-biologist would be able to abstract green spots into a story element but would be highly unlikely to devise a story element out of their absence. A different example of resorting to one's prior knowledge for story construction was found in a transition between an image of cells to an image of fewer cells. The player introduced apoptosis, i.e. cell death, in the narration although neither of the projects was related to the phenomenon. The inclusion of a technical term that was nowhere present in the content of the game attracted our attention; when asked, the player reported having had to study for a cell biology exam. Coping with (the ambiguity of) a pending storymove seems to be a challenge that demands creative solutions. As such, it requires the player not only to focus on the visual clues available but also to dig into her own baggage of prior knowledge and interests.

How did the players respond to storytelling with research images from the life sciences? All players 'moderately' enjoyed the game and both pairs voluntarily proposed to play the game with all four participants. With respect to the aims of the game, LABBOOK was clearly valued as a creative exercise and as a platform for conversation (cf. Table 5.1). All in all, players seemed to enjoy the game and experience. There was, however, some scepticism about the quality of the produced stories. One of the groups commented on their story being illogical, an aspect they attributed to the obscurity of combinations and to a lack of continuity. The perception of the players is of course respectable but it should be mentioned that many of the stories demonstrate a surprising degree of continuity with introduced characters active across a number of moves. Nonetheless, continuity could be better supported by means of the game's interface. For instance, we can consider a stage of active cards or a navigation aid to revisit the story so far. On the other hand, we have been conscious of the fact that our game does

not offer support for a narratively robust story construction. While we do not necessarily exclude this option, we have been mostly interested in the processes active during story-making rather than on the narrativity of the output stories. Another scepticism expressed regarded the relevance of biological content. The players commented that the game can be played with any type of images and were uncertain whether biological background or prior knowledge about the images assists story construction. The stories produced would suggest otherwise but we are wondering on the opportunities to better exploit the particularities of images from the life sciences.

5.6 Conclusion

This chapter introduced the notion of a story-based interaction with scientific images. By means of a literature review, preliminary user studies and the design and implementation of a concrete storytelling game, we have attempted to better understand the potential, relevant aspects and specific challenges of storytelling with scientific image data. During this process, we have identified requirements for better facilitating storytelling which we embody in the implementation of our collaborative storytelling game. Providing substantial support towards setting the right mindset for storytelling and considering less competitive modes of play are two of the design principles we wish to highlight. Last but not least, we have collected particularly encouraging story samples and user responses that further motivate the use of stories as a way to interact with research images. An active look into images and a shared conversation space appear to be two of the major contributions of a story-based interaction with images.

In its current implementation, LABBOOK is a well- functioning and well- received platform for collaborative storytelling with images. The game's interface is straightforward, the game rules are clear and unproblematic and story construction is stimulated by narrative, playful and social elements. Certainly, there is a lot to be done for LABBOOK to be released as a complete product. First of all, we need to implement functionality for players to load their images and access previously played stories. Secondly, we need to make better use of the tablet computer as a shared surface: Visual access to the storymove under narration is an important issue especially when images unknown to the players are involved. Eventually, we can always consider more elaborate ways to regulate either the initial image set or the transitions between storymoves. Potentially, we can also consider incorporating computational support for story composition or employing formal narrative elements as aids to story construction.

While we have examined the stories produced by our players attentively, our appreciation of them has been only subjective. At present, we lack a metric to evaluate the produced stories on either their quality or their usefulness. Such a metric may or may not measure the story's narrative quality and may or may not consider its scientific content. Nonetheless, a metric will be needed if we are to compare different prototypes or different games on the stories they facilitate. On the other hand, our examination of the produced stories focused on (attributes of) the story-making process, particularly the strategies, creative solutions and inspirations of our players. Moreover, we have been attentive for straightforward references to the image content as well as straightforward references to transitions between images. Regardless of the value of the stories themselves, such references allow us to raise a case for the value of story-making as a trigger for an active look into and in between images.

Finally, it should be noted that LABBOOK was designed as a platform that creates opportunities for storytelling in a shared and social context. The game mode implemented, i.e. a multiplayer game for players that are co-located, is a means to stimulate both storytelling and social interaction. The game has been valued as a creative exercise and as a platform for conversation and we are confident that it can accommodate the use case scenarios proposed. Regardless of the value of the output stories and regardless of the value of the story-making process, the opportunity for a shared conversation space and the playful exposure to one another's images and to one another may be just enough.

Chapter 6

Conclusion/Discussion

6.1 Overview

Congratulations! You made it to the last chapter. If you arrived here linearly, i.e. after having read all the previous chapters in their provided order, then the conclusion of this thesis will come as no surprise to you. I have discovered no law of nature; I was not looking for one at the first place. But I have learned plenty. Namely, I know to have:

- challenged, stretched, revised and revisited my own understandings and views on the core subjects of this thesis, i.e. play, science, creativity
- been many a times impressed by my users, their ideas and their capacity to find their own purpose and value in my ideas and artefacts; their input has been extraordinary useful, informative and enriching
- stumbled upon many a pitfalls, dead-ends, mistakes and circular problems which I am now aware of

That my understanding of my scientific field and the stance I take in it transformed during this research trajectory is of course the least to be expected. But what is there for others to learn out of my investigation? By conducting this research, I have:

- introduced ideas that are novel to current practices regarding interaction with scientific data in repositories, such as playful exploration (cf. chapter 1), video games for and out of repositories (cf. chapter 3) and storytelling with scientific images (cf. chapter 5)
- provided indications that these ideas are worth further exploring and implementing

- exposed some of the issues at stake when converting these ideas into concrete artefacts

The major contribution of this thesis is a broad but extensive investigation of playfulness as a desirable attribute of a scientist's interaction with scientific image data. We have argued elsewhere that playfulness is relevant for scientific practice in general and for exploring scientific image data in repositories in particular. Given our thesis, the question we asked was the following: What could playfulness with scientific images amount to and how do we design for it? Based on input from the literature, we selectively focused on associations as a relevant aspect of creative responses and insights over images. As a matter of fact, the notion of associations has been the common denominator in all the work presented in this thesis. To put it differently, we looked for, i.e. designed, implemented and evaluated, ways to produce gameplay that originates from a desire to exemplify or stimulate associations. In doing so, we have revisited current practices in playful and game-ful design within the domain of HCI. Rather than augmenting a task or interface with playful or game-full elements, our interfaces are playful in what they poke the user to do. At the end of the day, we can report on our own pitfalls, challenges, lessons learned and tensions identified during the development of our artefacts.

Section 6.2 briefly summarizes the key contributions of each chapter. For in-depth discussion, the reader is referred to the concluding section of each chapter. Here, we will mainly highlight novel concepts together with the findings that motivate further investigation of these concepts. Section 6.3 discusses some issues of importance to the design of playful interfaces. It offers a compilation of observations based on our practice which we hope to be of aid to other researchers interested in pursuing the idea of playfulness with scientific image data. Some of these observations have been addressed during our research trajectory, while others are suggestions for future work.

6.2 Summary of contributions per chapter

What could playfulness with scientific images amount to and how do we design for it? How do we produce gameplay that exemplifies or stimulates associations? What may be the added value of our interfaces/devised interactions? The preceding chapters have provided insight to such questions regarding the applicability of playfulness in the context of scientific image repositories.

Chapter 1, while an introductory chapter, provided a concise review on the core topics of this research. As such, it can be of relevance to (HCI) practitioners interested in scientific creativity, the role of images in the life sciences and the intersections of play and games with the domain of HCI. Based on literature, we introduced (a) playfulness as an attribute to be stimulated in interfaces to scientific image repositories and (b) associations as the focus point of play for the sake of exploration and creative responses to image data.

Chapter 2 proposed semantic annotation of image data as a viable approach to integration of image data across imaging modalities. As such, it emphasized the relevance and significance of connecting images for a better understanding of the phenomenon under study. Our work on the CSIDx database and interface highlighted the challenges of acquiring a complete annotation in a user-friendly manner. Visualization aids have been suggested to better exemplify the nature and structure of semantic, ontology-based metadata (cf. ontology viewer). Additional visualization aids have been introduced to better illustrate (attributes of) a result set as a whole (cf. search results visualization).

Chapter 3 introduced video games as 'executable' information visualisations, i.e. as a means to communicate the underlying structure of the data repository. Distinguishing of our approach is the requirement that gameplay should be directly derived from the graph structure of the dataset by enforcing a strong coupling between the game logic and the graph. The many potential mappings between game elements and graph elements open up a wide range of potential games and we consider our approach also an original strategy for producing new video games. The development of a concrete game allowed us to comment on the potential of video games as 'executable' information visualizations: Exposure to the game seems to contribute to the user's mental model of the data collection and data organization while converting an aspect of the system into something relevant for the player, e.g. score, allowed the player to react on an important aspect of the system, i.e. annotations.

Chapter 4 provided insights into user-moderated, image-based gaming activity in the Flickr photo sharing system. We supplied a first understanding of the various ways Flickr groups engage in play, a first categorization of the types of games played and some observations on the mechanics involved. Next to being a small step in classifying the rather unstructured environment of Flickr groups and games, our study contributes some suggestions on possible formats of gaming with images. Flickr games may not always comply to a strict definition of the term 'game', although they are clearly perceived as games by their initiators and participants. Considering activities without an explicit winning condition introduces

new directions for play and playfulness with images. What is more, we observed that players often value ambiguity as a source of play. Employing ambiguity as a design principle is another exciting direction that gaming with images can head in.

Chapter 5 introduced storytelling as a form of playing with scientific images. This chapter demonstrated a shift towards less rule-bounded play activities such as storytelling and a shift towards social aspects of scientific creativity. We observed that researchers can engage in storytelling with scientific images if properly prepared and prompted to. The development of a collaborative storytelling game for biologists and their images further allowed us to comment on the potential of storytelling with scientific images. By confronting the players with the challenges of story composition, the game has demonstrated a capacity of storytelling to probe an active look into and in between the images involved.

6.3 *In lieu* of design guidelines

This section summarizes issues we identify as important for the design of playful interfaces to scientific image collections. Truth is, we advocate that there can be no one-size-fits-all solutions when designing for playfulness. But if you find it worthwhile to study or create gameplay for playful interactions with scientific image data, our own practical experiences and, particularly, our false starts may be of some use. Subsection 6.3.1 discusses methodological and design challenges while subsection 6.3.2 discusses opportunities for future work. Nonetheless, the boundaries between the two are blurred as all identified challenges are opportunities for future work.

6.3.1 Points of tension, points of attention

Interface design *vs* Game design

The games produced during this research were created mainly by means of HCI methods. In particular, the design iterations of Onto-Frogger were predominantly focused on the interface of the specific game while the development of LABBOOK was, in part, an effort to extract requirements by considering our users' reactions to storytelling with scientific images. We have discussed elsewhere the significance of a well-designed interface for the experience of the user/player and for the success of the platforms we like to call playful interfaces for exploration. That said, we realize that more experimentation regarding the game concepts of our artefacts would have been welcome. Note that the same HCI practices, e.g. fast

prototyping, user-centred design, etc., can be still employed but with a different objective, i.e. an appropriate set of game rules.

The impact of the interface, in one hand, and of the game concept, on the other, to the overall quality of a prototype is a cumbersome issue. When a prototype 'fails', is it the interface that is inappropriate or the game concept? How far should one improve on the one (and which one?) before rejecting the other? This circular trap has implications not only for the evaluation of a prototype but also for the evaluation of the research question the prototype relates to. Our research methodology was to, a great extent, based on the following assumption[1]: That the design of artefacts can promote understanding by, firstly, confronting the researcher with the challenges of making concrete products out of theoretical propositions and, secondly, by providing a tangible tool for the researcher to interact with the users. Unavoidably, this approach suffers from the same circular trap: When an idea 'fails', is it the prototype that is inappropriate or the suggested theory? We have decided to ignore this loophole by accepting that our artefacts are not controlled experiments to prove our theories but probes for a useful exchange with our users.

Designing for users *vs* Designing with users

As far as we are entitled to say, this research has been be user-centred for placing the interests and experiences of our users at its core. Yet, we are fully aware that one can not design an experience and that, regardless of how grounded our theoretical propositions are, users will respond to our ideas and artefacts in their own unique and situated ways. Eventually, the only value or usage our artefacts can aspire to is not the one we predict but the one our users will assign or discover in them. This realisation is particularly relevant when introducing new practices that do not necessarily reflect the articulated needs or established workflows of a user group. In this case, we can only invite our users to consider the practices we believe worthwhile. While doing so, we need to resist the urge to prove our ideas and remain open to what our users may make of them.

There is much we can learn from our users, also in exchanges other than user evaluation sessions. Our Flickr study (cf. chapter 4) is a straightforward example of turning to a community of players in order to learn from their own self-initialized and self-moderated practices. More opportunities to learn directly from our target user group would have been appreciated. By this, we refer to both opportunities for observation as in ethnographic studies, research in the

[1]The notion of research-through-design as discussed by Zimmerman et al. (2007) is relevant but not exactly equivalent to our approach.

wild (Chamberlain et al., 2012), etc. and opportunities for participatory design. Empowering the users to imagine and create their own interactions would have added an entirely new dimension to the ideas presented in this thesis.

Playing with images: Gamification *vs* Design for playfulness

The artefacts produced during this research have been intended as playful interfaces to scientific data. We devised and investigated possible ways to literally play with scientific images in manners that would potentially stimulate exploration as in identifying patterns, making associations, embracing ambiguity and participating in social exchange. Our approach has been diametrically opposed to superficially layering playful or game-full element in an existing application. And while most of our outputs are comparable to serious games, we acknowledge that making playful interfaces does not necessarily equal with making games. Nor is making games a panacea when playfulness is the objective. What we mean to say is that, in order to support play for exploration, making games is not enough. Making games that focus on what is intrinsically valuable and relevant for exploration may be a step in the right direction.

Onto-Frogger and LABBOOK were both driven by the same interest and motivation but are two very different games. Out of their many differences, we would like to highlight that Onto-Frogger values and utilizes the formal rule structure of a game while LABBOOK values and utilizes storytelling as a form of free and creative play. Without dismissing the potential of rule-bounded games, we come to realize that unstructured play activities may be more appropriate towards supporting exploration and creativity. Next to playing as gaming and playing as creating (stories), a notion of play that is still pending our investigation is the notion of playing as having freedom of control. This research has considered playful exploration as in browsing, building a mental model, establishing associations, actively looking into entities but it is still to consider exploration as in being in total control in experimenting with options and alternatives.

6.3.2 Future challenges, future directions

Interacting with images: Pixel data *vs* Metadata

From the onset of this project, our affirmation was that images from the life sciences are composite entities of pixel data and metadata. Image captures without metadata are, to put it mildly, unusable for a data repository and for other researchers. Our interest in associations runs in parallel to our interest in metadata, in particular semantic metadata that provide an integration of images over

subject matter. The projects developed during this research range from communicating existing connections based on metadata to establishing new connections between image entities. In both cases, our focus lies in whatever useful knowledge or insight exists in the space in-between image entities. However, and as our storytelling game indicates (cf. chapter 5), there is plenty of useful input in the pixel content of a single image. Therefore, an active look into a single image is a contribution we would like to push further. Potentially, our notion of video games as 'executable' information visualizations could be expanded to the pixel level. A game that is an 'executable' visualization of a single image would require that aspects of the pixel content of the image are properly encoded into the rules of the game.

Interacting with images: Single image entities *vs* High-throughput images

This thesis has considered the role of images in a research trajectory and the contribution of image-based observations as signposts in ongoing research. While we consider an image entry, i.e. pixel data and metadata of a single capture, as self-contained, we are more and more aware that a shift is mediated by the predominance of high-throughput imaging in the life sciences. The outputs of a high-throughput experiment involving imaging are better consumed and incorporated in the form of graphical representations of derived numerical data. The captured snapshots are simply too numerous to inspect, although they will be consulted and inspected once an interesting outlier in the graphic is found. Playing with images could be easily propagated into playing with graphs while the notion of associations is particularly forgiving about the type of data to be contrasted, compared and linked.

Interacting with images *vs* Interacting with researchers

This thesis has considered ongoing research in scientific practice as a process of transformation, i.e. a process of refining one's research experiments and choices by incorporating image-based observations. Such observations can be facilitated by various mechanisms such as a new look into one's own image data, a new association between one's own image data and one's repository of background knowledge, or a new association between one's own data and the data of another researcher. This approach can be understood as an image-centred one and one that assumes that the observation, negotiation, synthesis or inference occurs as the researcher solely processes hers or others' image data. However, we have been increasingly aware of the importance of social exchange and conversation

during a research trajectory. Exposure to the images of other researchers is undoubtedly beneficial but so is exposure to other researchers themselves. We suggest that future instances of playful interactions with scientific images should further examine the role of social interaction and exchange. In other words, playing with scientific images should be further expanded to also consider playing with other researchers.

6.4 Wrapping it all up: A plea for true playfulness and another one for true participatory design

If I were to start all over again, I would have done it all differently. This is not to say that the turns I took were the wrong ones, only that I now have a different perspective on and understanding of the possibilities and directions to be explored. Even so, I am confident that the part of the road that was travelled was not for nothing. When me or any other researcher wish to study, employ or exploit play and playfulness with scientific images, we will not start entirely blind.

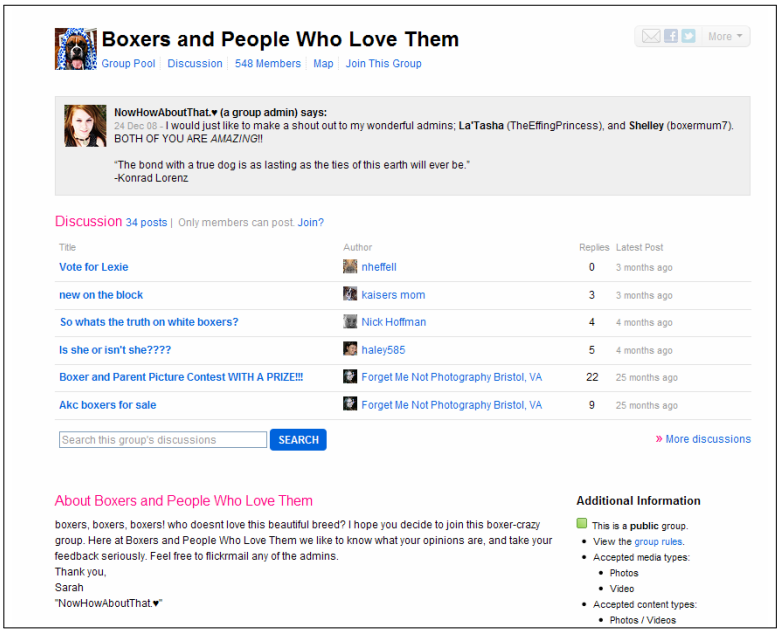
This thesis will now conclude with a plea. Forget about gamification, forget about playful interfaces. When designing for playfulness and/or exploration, try to understand what is inherently useful and playful in scientific practice or any other task in hand for that matter. And build your games, interfaces or experiences with this element at the core. As far as methodology is concerned, make it truly participatory as early as you can. You will be surprised how much your users can do.

All things considered, I still believe that coupling playfulness and scientific data is a worthwhile idea. Up to this point, I have tackled only a small subset of what playing with scientific images can be; the rest is up to you.

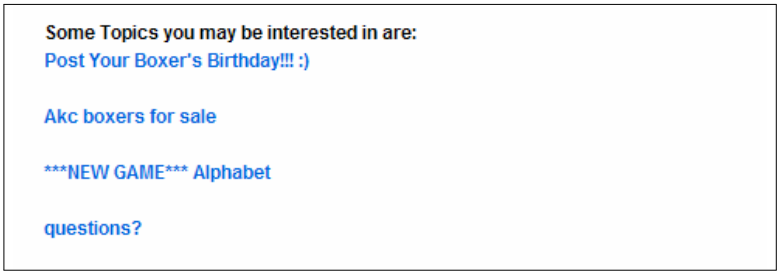
Appendix A

Examples of Flickr groups per theme

All screenshots captured in May 2011.

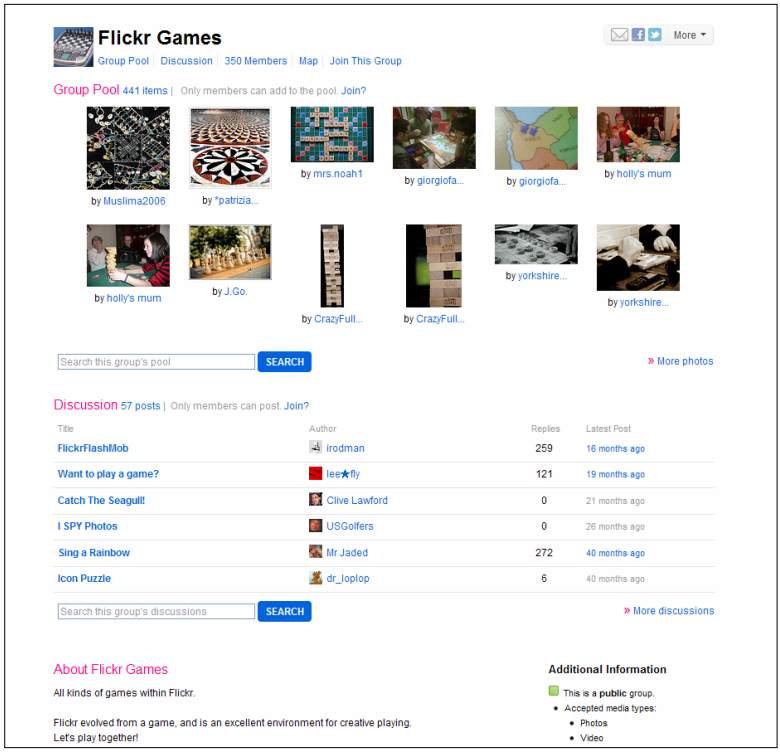


(a) group homepage (partial view)

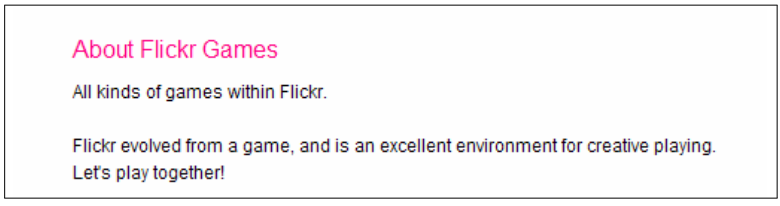


(b) detail

Figure A.1: Gaming as secondary activity. Groups of various topics may play threaded games in their message boards. Here the 'Boxers And People Who Love Them' group playing an instance of the ABC game (group URL: http://www.flickr.com/groups/boxersandpeoplewholovethem/).

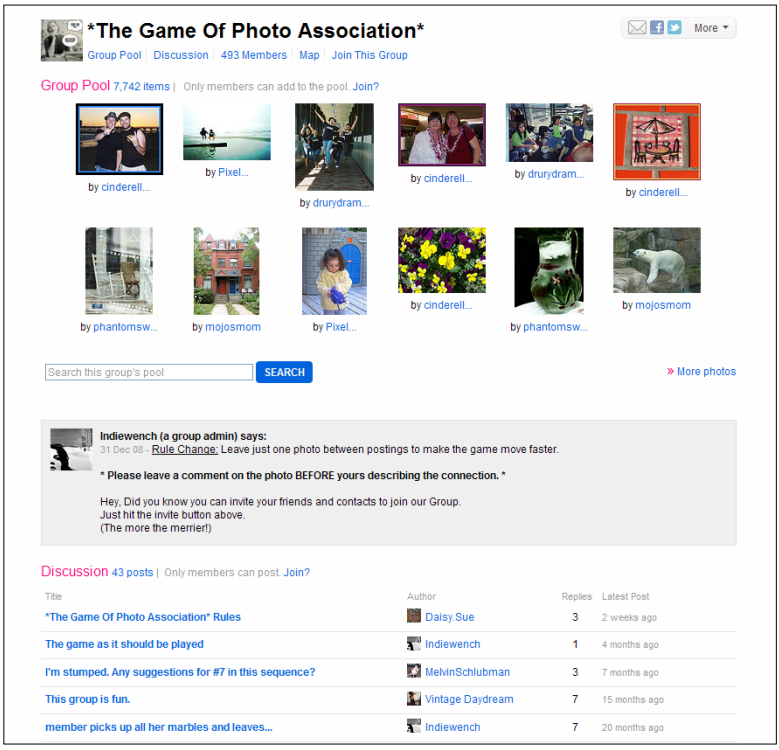


(a) group homepage (partial view)

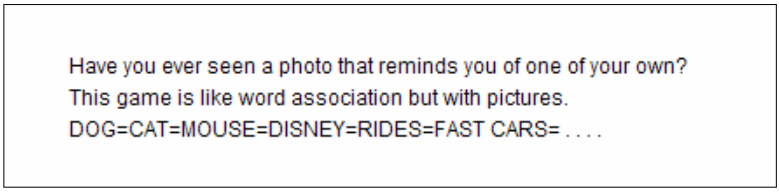


(b) detail

Figure A.2: Gaming as core activity. A number of groups are specifically created for the purpose of playing games among their members. Here the 'Flickr Games' group maintaining a collection of several known threaded games (group URL: http://www.flickr.com/groups/flickrgames/).

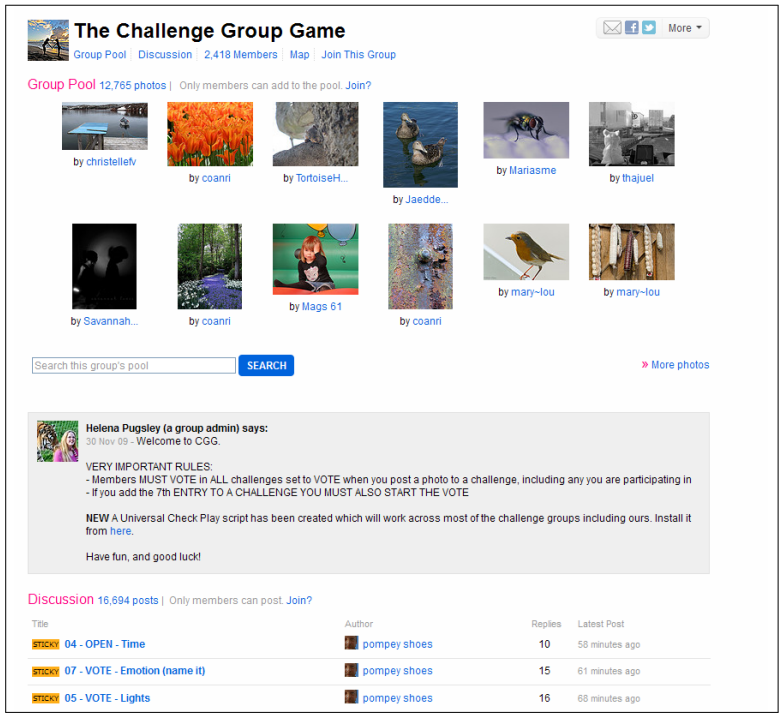


(a) group homepage (partial view)



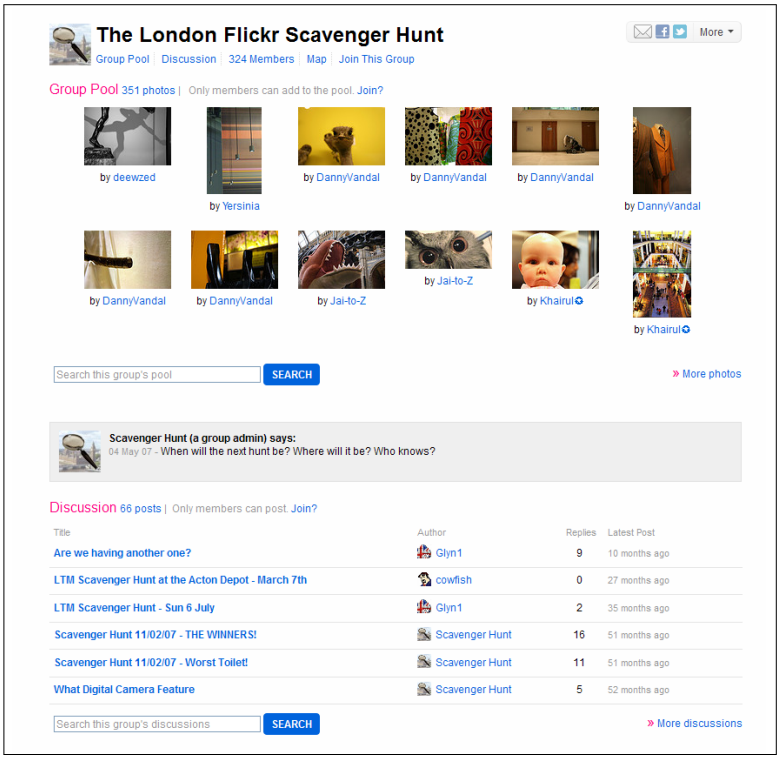
(b) detail

Figure A.3: Gaming as core activity. Groups dedicated to gaming may maintain several threaded games (cf. Figure A.2) or be dedicated to one type of game. Here the 'The Game Of Photo Association' group playing a single instance of a Photo association game in the pool of the group (group URL: http://www.flickr.com/groups/gameofphotoassociation/).

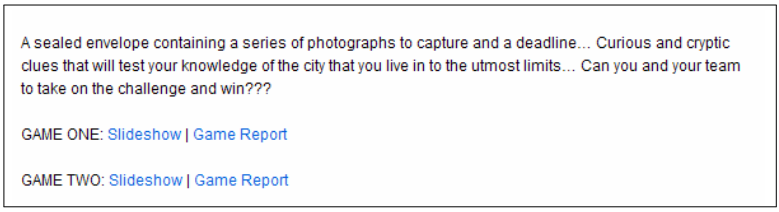


(a) group homepage (partial view)

Figure A.4: Gaming as contest. A number of groups are specifically created for the purpose of conducting image challenges and contests. Here the 'The Challenge Group Game' group (group URL: http://www.flickr.com/groups/the_challenge_group/).



(a) group homepage (partial view)



(b) detail

Figure A.5: External gaming activity. Groups may engage in games or playful activities that are photo-oriented but performed outside the Flickr system. Here the 'London Flickr Scavenger Hunt' (group URL: http://www.flickr.com/groups/london_flickr_scavenger_hunt).

Appendix B

Playtesting stories: Cards

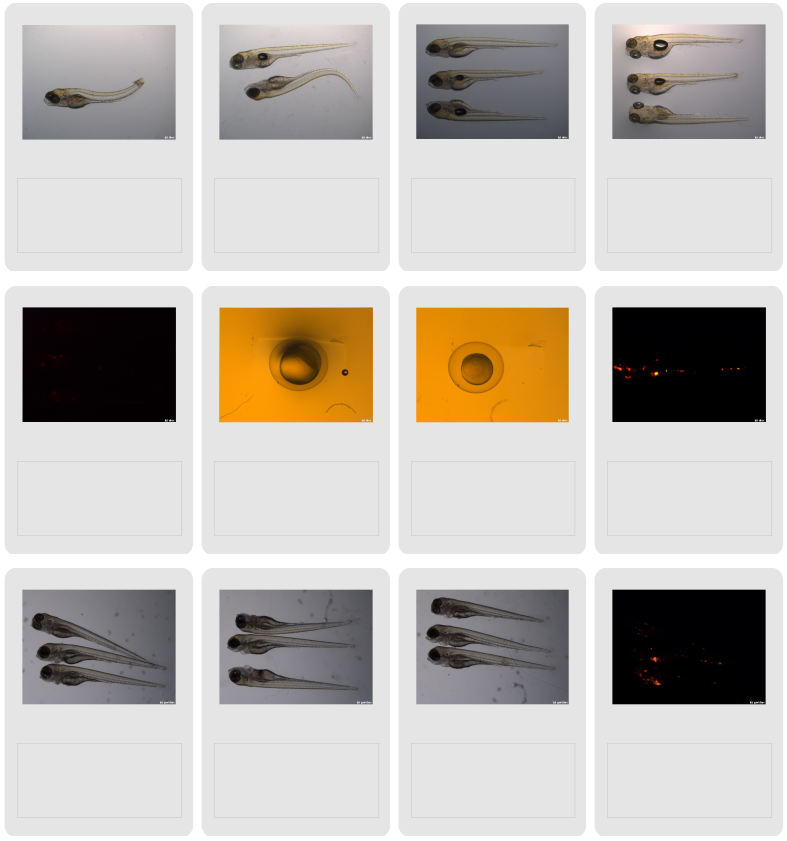


Figure B.1: Image cards as derived from research images provided by the participants.

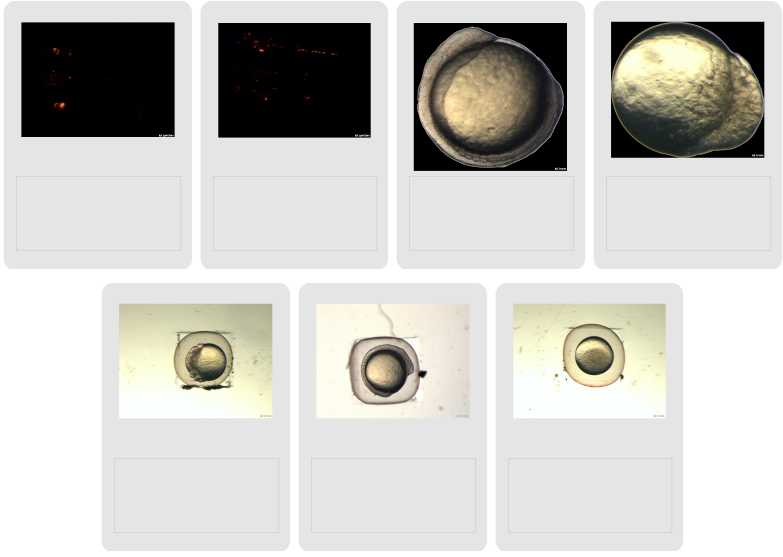


Figure B.1: Image cards as derived from research images provided by the participants (cnt.).

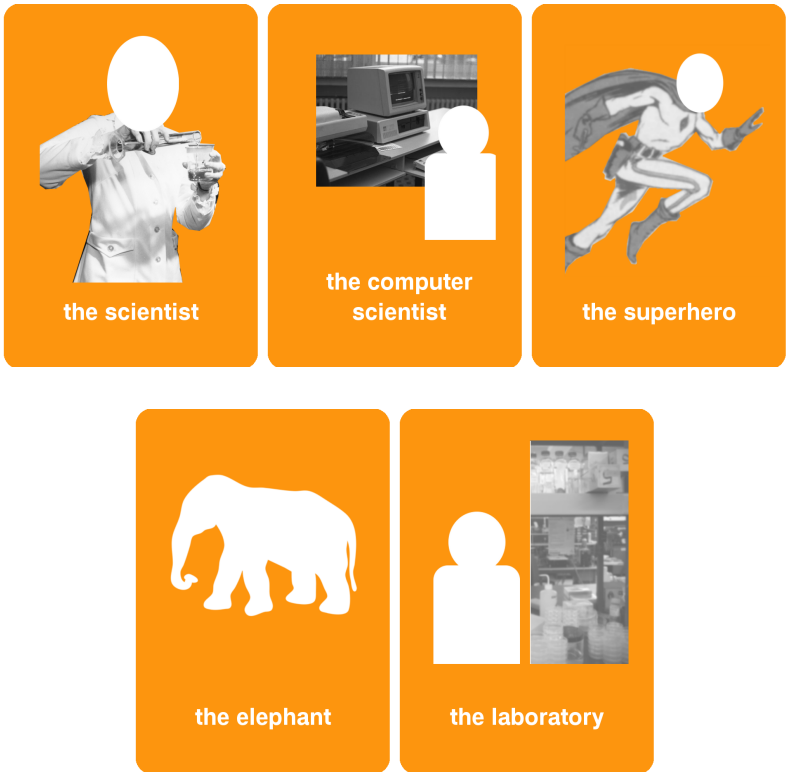


Figure B.2: Utility cards with characters.

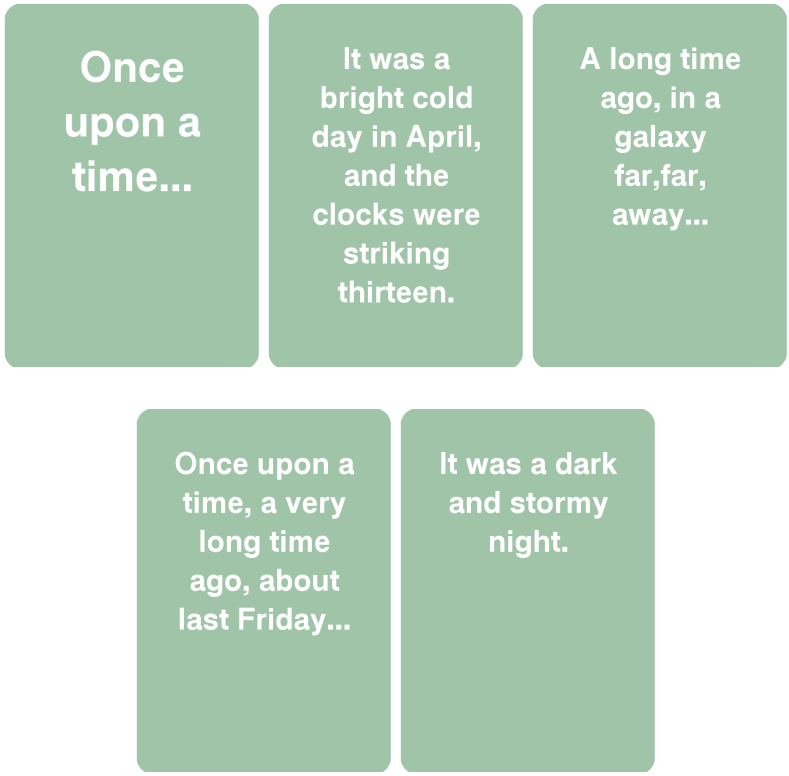


Figure B.3: Utility cards with opening lines.

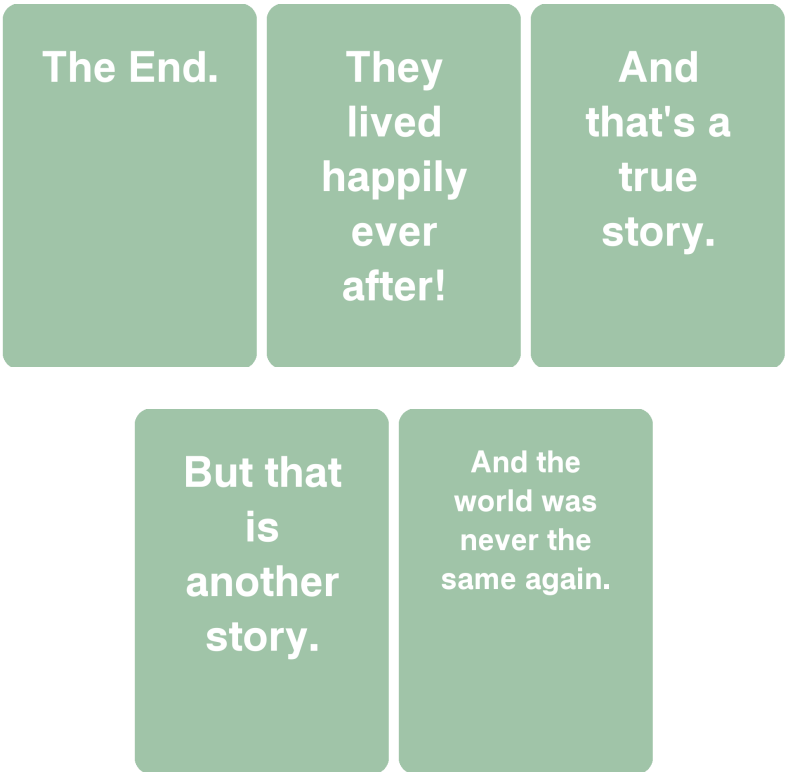


Figure B.4: Utility cards with closing lines.

Figure B.5: Utility cards with common literary genres.

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Summary

Scientific practice is an activity that is data-intensive and widely supported by computerized systems, data repositories included. It is also an activity that is highly creative and, as such, can benefit from a moment of openness, playfulness and exploration. This thesis contributes a broad but extensive investigation of playfulness as a desirable attribute of a scientist's interaction with scientific image data. We argue that playfulness is relevant for scientific creativity in general and for exploring scientific image data in repositories in particular. Given our thesis, the question we ask is the following: What could playfulness with scientific images amount to and how do we design for it? Via case studies and reviews, we flesh out particular elements of play for exploration and implement artefacts that exemplify instances of playful interaction with image research material in collections.

Chapter 1 provides a concise review on the core topics of this research, namely scientific creativity, the role of images in the life sciences, discovery and exploration in data collections and the meeting points of play and games with the domain of Human Computer Interaction (HCI). Based on this material, we propose (a) playfulness as an attribute to be stimulated in interfaces to scientific image repositories and (b) associations as the focus point of play for the sake of exploration and creative responses to image data.

Chapter 2 introduces the CSIDx database (Cyttron Scientific Image Database for eXchange), a multi-modal imaging database for images produced in the life sciences. In CSIDx, we aim for an integration of images across imaging modalities, i.e. across various microscopy techniques operating at different levels of detail. Semantic annotation of images is proposed as both the means to link modalities and a necessary requirement for image sharing and reuse. Our work on the CSIDx database emphasized the significance of linking images for a better understanding of the biological phenomenon under study. It also emphasized ontology-based metadata as a core aspect of the image collection. Information visualization aids were introduced to better communicate the nature and structure

of semantic, ontology-based metadata (cf. ontology viewer). Additional visualization aids were introduced to facilitate browsing and to better illustrate (attributes of) the collection as a whole (cf. search results visualization).

Chapter 3 presents Onto-Frogger, a video game developed for the CSIDx database. Onto-Frogger is a single-player, arcade style game for scientific images, their annotations and the connections established by these annotations. The game abstracts the CSIDx database to a graph of images that are interconnected because of their annotations. Onto-Frogger aims to familiarize the players with the idea that images in a (semantically enriched) collection are interconnected and to invite them to identify, predict and resolve various connections during gameplay. To achieve this, we propose a strong coupling between the graph and the game logic: Features of the graph are used to control the progress of the game, to decide upon its outcome and to score the player actions. As such the game becomes a form of 'executable' information visualization that materializes connections rather than visualizing them. Exposure to the game seems to contribute to the user's mental model of the data collection and data organization. In addition, converting an aspect of the system into something relevant for the player, e.g. score, allowed the player to react on an important aspect of the system, i.e. annotations.

Chapter 4 takes a step away from the CSIDx database to examine what lessons can be learned from existing practices in popular image collections and from existing games involving digital images. Chapter 4 reviews image-based gaming activity in the Flickr photo sharing system. We supply a first understanding of the various ways Flickr groups engage in play, a first categorization of the types of games played and some observations on the mechanics involved. Next to being a small step in classifying the rather unstructured environment of Flickr groups and games, our study contributes some suggestions on possible formats of gaming with images. Flickr games may not always comply to a strict definition of the term 'game', although they are clearly perceived as games by their initiators and participants. Considering activities without an explicit winning condition introduces new directions for play and playfulness with images. What is more, we observed that players often value ambiguity as a source of play. Employing ambiguity as a design principle is another exciting direction that gaming with images can head in.

Chapter 5 presents LABBOOK, a collaborative storytelling game for biologists and their images. Motivated by the findings of our Flickr study, we looked for ways to play with images that are less rule-bounded. More specifically, LABBOOK was motivated by an interest in the qualities of stories and storytelling. Stories and storytelling have been extensively used as a means to probe articulation, to invite

creative play and to impose coherence and structure. Stories provide a mechanism to synthesize parts into an intelligible whole and a faculty to articulate about experiences or ideas. LABBOOK aims to probe similar processes by inviting players to build a story with their research images. LABBOOK is also a platform for social exchange and interaction between researchers. By confronting the players with the challenges of story composition, the game has demonstrated a capacity of storytelling to probe an active look into the images involved.

In the course of this research, we devised and investigated possible ways to literally play with scientific images in manners that would potentially stimulate exploration and creativity as in identifying patterns, making associations, embracing ambiguity and participating in social exchange. Our case studies have resulted in a number of encouraging observations and user responses. All in all, we hope to have motivated fellow HCI researchers and HCI practitioners to research and/or to implement playful interactions with scientific image data in repositories.

Samenvatting

Het wetenschappelijke bedrijf is data-intensief, grote dataverzamelingen en gecomputeriseerde systemen spelen een belangrijke rol. Het is tevens een activiteit die zich kenmerkt door een grote mate van creativiteit en als zodanig kan het baat hebben bij momenten van openheid, speelsheid en verkenning. Dit proefschrift draagt hieraan bij met een breed en uitgebreid onderzoek naar speelsheid als wenselijk onderdeel in de interactie van onderzoekers met hun wetenschappelijk beeldmateriaal. Wij nemen het standpunt dat speelsheid van belang is voor creativiteit in het wetenschappelijke proces en in het bijzonder voor de verkenning van wetenschappelijke beeldverzamelingen. Daarom staat in dit proefschrift de volgende vraag centraal: "wat kan speelsheid toegepast op wetenschappelijk beeldmateriaal bijdragen, en hoe moet er dan voor speelsheid worden ontworpen?". Door "case"–studies en literatuur/bronnen onderzoek analyseren wij specifieke spelelementen die voor verkenning van belang zijn. Daarbij hebben wij enkele testapplicaties gemaakt die als voorbeeld dienen voor speelse interactie met wetenschappelijk beeldmateriaal uit grote verzamelingen.

In Hoofdstuk 1 wordt een beknopt overzicht gegeven van de kernonderwerpen uit in dit proefschrift, te weten: wetenschappelijke creativiteit, de betekenis van beelden in de levenswetenschappen, verkenning en ontdekking in dataverzamelingen en de gemeenplaatsen van speelsheid en spel met het onderzoeksgebied van Mens Machine Internactie (Eng. *Human Computer Interaction*, HCI). Gebaseerd hierop, wordt voorgesteld (a) "speelsheid" als eigenschap van interactieve software voor wetenschappelijk beeldmateriaal te stimuleren, en (b) het maken van associaties voor creatieve verkenning van wetenschappelijk beeldmateriaal te benadrukken via spel.

In Hoofdstuk 2 wordt CSIDx (Cyttron Scientific Image Database for eXchange) geïntroduceerd. Dit is een database specifiek ontworpen ter ondersteuning van de keur aan verschillende beeldmodaliteiten in de levenswetenschappen. In CSIDx wordt integratie van beelden van verschillende beeldmodaliteiten nagestreefd, te

weten, microscopische technieken kenmerkend voor verschillende niveaus van detail. Er wordt een semantisch annotatieproces voorgesteld om verschillende beeldmodaliteiten aan elkaar te kunnen relateren, een eis voor het delen en hergebruiken van beelden. Ons onderzoek met de CSIDx database benadrukt het belang van het leggen van relaties tussen beelden teneinde een beter begrip te krijgen omtrent het biologische fenomeen dat wordt bestudeerd. Daarnaast wordt in dit onderzoek ook het belang van metadata gebaseerd op ontologieën als kerneigenschap van een beeldverzameling benadrukt. Technieken uit de informatievisualisatie worden geïntroduceerd om de aard en de structuur van de semantische ontologie-gebaseerde metadata naar gebruikers te communiceren. Daarnaast zijn er visualisatie applicaties toegevoegd om het doorzoeken van de verzameling in CSIDx te vergemakkelijken en tegelijkertijd een goede indruk te verschaffen van de verzameling beelden als geheel.

In Hoofdstuk 3 wordt Onto-Frogger gepresenteerd, een videospel dat werd ontwikkeld voor de CSIDx database. Onto-Frogger is een *single-player* arcade-stijl spel gebasseerd op wetenschappelijke beelden, annotaties van die beelden en de verbindingen tussen deze beelden op basis van de annotaties. Het doel van Onto-Frogger is de speler vertrouwd te maken met het concept dat beelden in een semantisch verrijkte beeldverzameling verbonden zijn en de speler uit te nodigen om verschillende verbindingen te identificeren, te voorspellen en te verklaren. Om dit te bereiken wordt een sterke verbinding tussen de onderliggende graaf en het spelverloop gelegd; de eigenschappen van de graaf worden gebruikt om de voortgang van het spel te controleren, de uitkomst vast te stellen en activiteiten van de speler te beoordelen. Op deze manier verwordt het spel een vorm van “executeerbare” informatievisualisatie waarin relaties op meer wijze betekenis krijgen dan in visualisatie alleen. Het spelen van dit spel lijkt bij te dragen aan het mentale model dat de gebruiker van een verzameling data en de organisatie daarvan heeft. Bovendien, het omzetten van een bepaald aspect van het systeem in iets dat voor de speler relevant is, bijvoorbeeld een puntentelling, maakt het mogelijk om te reageren op een belangrijke eigenschap van het systeem, te weten, annotaties.

In Hoofdstuk 4 wordt enigermate afstand genomen van de CSIDx database en wordt onderzocht welke lessen er zouden kunnen worden geleerd uit populaire digitale beeldverzamelingen en bestaande spelvormen die daarop betrekking hebben. Daartoe wordt in Hoofdstuk 4 een studie gepresenteerd aangaande beeldgebaseerde spelactiviteiten in het Flickr foto-uitwisseling systeem. Wij geven een eerste analytische aanzet omtrent de verschillende manieren waarop gebruikersgroepen in Flickr zich bezighouden met spelvormen, een opzet voor categorisatie van deze spelvormen en observaties met betrekking tot de onderliggende

spelmechanismen. Naast het zetten van de eerste schreden in de classificatie van de nogal ongestructureerde wereld van gebruikersgroepen en spelvormen in Flickr, draagt deze studie bij aan het formuleren van mogelijke formats voor spelvormen met beelden. De spelvormen in Flickr rijmen niet altijd met een strikt gehanteerde definitie van het concept “spel”, echter de initiatiefnemers en de deelnemers aan deze spellen ervaren het wel degelijk als “spel”. Spelactiviteiten zonder een expliciete voorwaarde voor het winnen, zoals gebruikelijk in Flickr, openen nieuwe wegen voor spelvormen en speelsheid met beelden. Daarnaast hebben wij waargenomen dat binnen deze gemeenschap spelers dubbelzinnigheid waarderen als een wezenlijk onderdeel van het spel. Het gebruiken van dubbelzinnigheid als ontwerpprincipe is een interessante richting die gevolgd kan worden voor het ontwerpen van spellen met beelden.

In Hoofdstuk 5 wordt LABBOOK gepresenteerd, een spel voor collaboratieve vertelkunst voor onderzoekers in de levenswetenschappen en hun beelden. Gemotiveerd door de bevindingen uit Hoofdstuk 4 onderzochten wij manieren om met beelden te spelen die minder gebonden zijn aan regels. Meer in het bijzonder is de ontwikkeling van LABBOOK gedreven door een belangstelling in eigenschappen van verhalen en vertelkunst. Verhalen en vertelkunst zijn een geschikt middel om uitlatingen te ontlokken, om tot spel uit te nodigen en om samenhang en structuur aan te brengen. Verhalen bieden een mechanisme om delen samen te voegen tot een inzichtelijk geheel en ideeën en ervaringen te formuleren. Het doel van LABBOOK is om dergelijke processen aan te boren door de spelers uit te nodigen een verhaal te bouwen met de beelden uit hun onderzoek. Daarmee wordt LABBOOK ook een platform voor sociale uitwisseling en interactie tussen onderzoekers onderling. Door spelers de uitdaging van het samenstellen van een verhaal te bieden, illustreert LABBOOK het vermogen van vertelkunst om een actieve houding t.a.v. de betreffende beelden te ontlokken.

In de loop van dit onderzoek zijn een aantal mogelijkheden geopperd en onderzocht om, letterlijk, te spelen met wetenschappelijk beeldmateriaal op manieren die speurwerk en creativiteit in het vaststellen van patronen stimuleren, associaties maken, dubbelzinnigheid aanvaardbaar maken en deelnemen in sociale uitwisseling. Onze “case”-studies hebben geleid tot enkele bemoedigende waarnemingen en reacties van gebruikers. Alles welbeschouwd, hopen wij dat we collega onderzoekers/beoefenaars in het veld van de Mens-Computer Interactie (HCI) hebben gemotiveerd tot verder onderzoek en implementatie van speelse interacties met wetenschappelijke beelddata zoals deze bestaan in beeldverzamelingen.

Curriculum Vitae

Amalia Kallergi was born in Thessaloniki, 1979. She studied Computer Science at Aristotle University of Thessaloniki (BSc, graduated 2002) and Media Technology at Leiden University (MSc, graduated 2006). From 2007 till early 2008, she worked as a scientific programmer for the Imaging & Bioinformatics group, Leiden University; in March 2008, she started her PhD research at the same research group. Amalia Kallergi has been concurrently a researcher, a teacher, a student and an honours class coordinator.

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