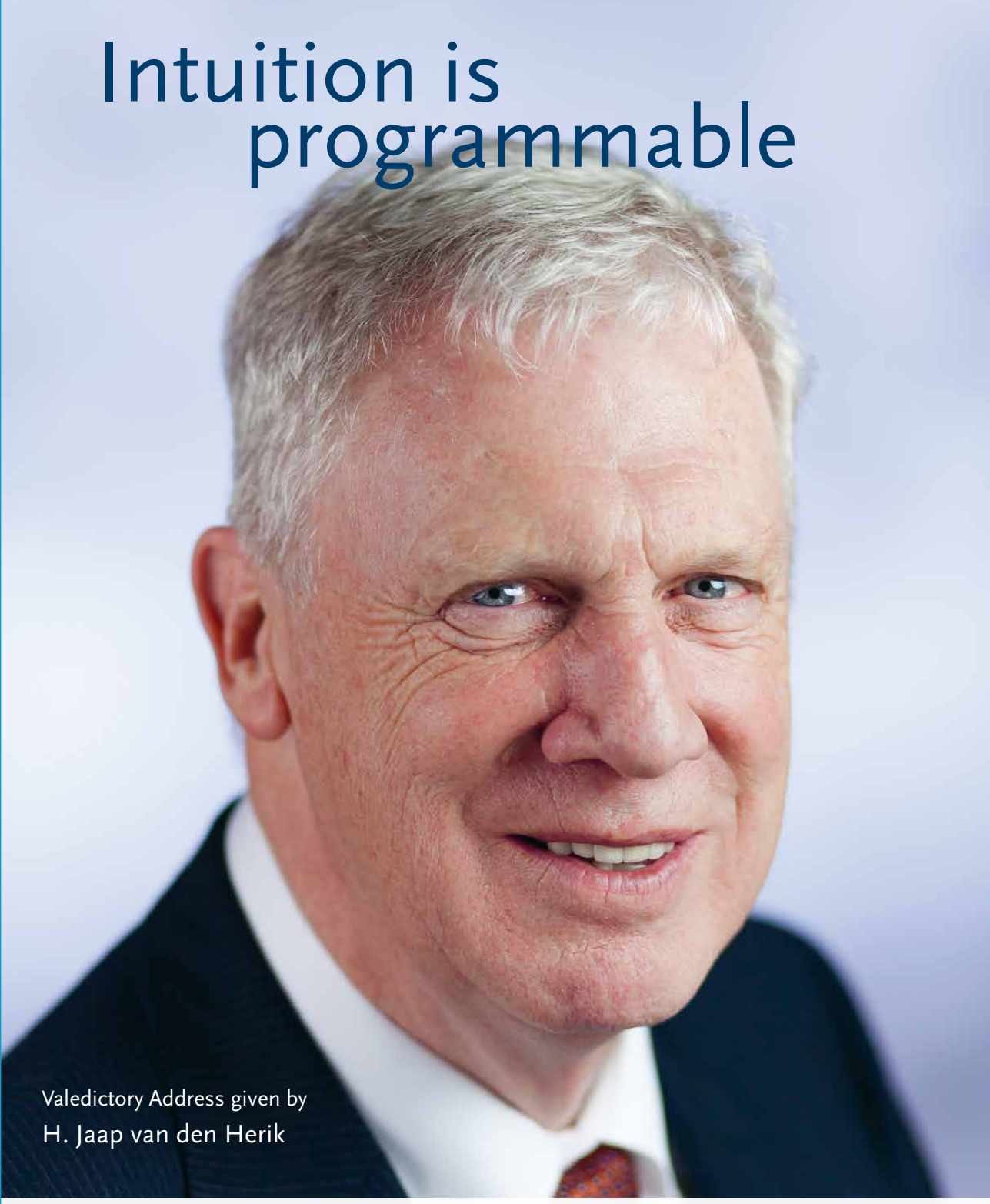
Intuition is programmable



Valedictory Address given by

H. Jaap van den Herik

Tilburg University

Understanding Society

Jaap van den Herik (1947) studied mathematics at the Vrije Universiteit Amsterdam (with honours), received his Ph.D. degree at Delft University of Technology in 1983 and was appointed as full Professor of Computer Science at Maastricht University in 1987. In 1988 he was appointed as part-time Professor of Law and Computer Science at the Leiden University. In 2008, he moved as Professor of Computer Science to the Tilburg University (2008-2016). He is the Founding Director of IKAT (Institute of Knowledge and Agent Technology) and TiCC (Tilburg center for Cognition and Communication). In the Netherlands he initiated the research area e-Humanities. Moreover, he was supervisor of 71 Ph.D. researchers. He was active in many organisations, such as JURIX (Honorary Chair), the BNVKI (Honorary Member), the CSVN (Honorary Member), the ICGA, NWO-NCF, ToKeN, CATCH, and the consortium BIGGRID. Van den Herik is ECCAI fellow since 2003, member of the TWINS (the research council for sciences of the KNAW) and a member of the Royal Holland Society of Sciences and Humanities (KHMW). In 2012 he was co-recipient of an ERC Advanced Research Grant (together with Jos Vermaseren (PI, Nikhef) and Aske Plaat). On January 1, 2014 the appointment at the Faculty of Law was broadened to the Faculty of Science. Together with Joost Kok and Jacqueline Meulman he launched Leiden Centre of Data Science (LCDS) and is Chair of the Board of LCDS.

BNVKI	–	Belgian Netherlands Association of Artificial Intelligence
CATCH	–	Continuous Access To Cultural Heritage
CSVN	–	Computer Chess Association in the Netherlands
ECCAI	–	European Coordinating Committee for Artificial Intelligence
ERC	–	European Research Council
ICGA	–	International Computer Games Association
IKAT	–	Institute of Knowledge and Agent Technology
KHMW	–	Royal Holland Society of Sciences and Humanities
KNAW	–	The Royal Netherlands Academy of Arts and Sciences
LCDS	–	Leiden Centre of Data Science
NCF	–	Foundation of National Computer Facility
NWO	–	Netherlands Organization for Scientific Research
TiCC	–	Tilburg center for Cognition and Communication
ToKeN	–	Towards Knowledge Engineering Netherlands
TWINS	–	The Council for Technical Sciences, Mathematical Sciences and Informatics, Physics and Astronomy and Chemistry

Intuition is programmable

H. Jaap van den Herik

Valedictory Address
Presented in abbreviated form at the public farewell to the office of Professor of Computer Science at the Tilburg center for Cognition and Communication (TiCC) of the Faculty of Humanities of Tilburg University on Friday, January 29th, 2016

with gratitude to Joke Hellemons and Eefje Kruijs Voorberge
for taking care of the text

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ISBN: 978-94-6167-268-1

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www.tilburguniversity.edu

Intuition is programmable

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1
Is Contradiction Original?

Honourable Rector Magnificus, honourable Dean,
ladies and gentlemen associated with Tilburg University
and also all of you whose presence gives this ceremony its dignity,
highly esteemed audience!

Today I officially complete a period of 88 months during which I served Tilburg University. I enjoyed my time at this wonderful institution. With a team of enthusiastic and talented colleagues I was able to build a flourishing research infrastructure, and accomplished many other things. I mention here the creation of the Tilburg Center for Cognition and Communication (TiCC).[1] Perhaps designing TBDL[2] which was the start of the big data explosion in Brabant is even more important. However, today I will discuss other matters. I want to focus on the Ph.D. students who I supervised in the period from September 1, 2008 to January 1, 2016. I will make two exceptions, namely for Guido de Croon who graduated from Maastricht University on June 26, 2008 and for Ruud Mattheij who hopes to graduate from Tilburg University in 2016.

1.1 The Run-up

In 1978 I was able to turn my hobby into my profession. I embarked upon an ambitious Ph.D. project which would take nearly five years. It was entitled *Computer Chess, the World of Chess, and Artificial Intelligence*. I had many mentors, three of them would eventually become my supervisors, namely Professor H.J.M. Lombaers, Professor A.D. de Groot and Professor S.J. Doorman. Lombaers knew at that time, everything about computers, De Groot about the thinking of a chess player, and Doorman about analytic philosophy.

The first meeting on the research project with De Groot had traits of the puppy and the old master (by the way, we were chess friends and opponents in several rapid chess tournaments). "Professor, I am considering implementing your theories about the thinking of the Chess player (De Groot, 1946) in a computer program and much more. Over time, this research will lead to a program that will play stronger than the human world champion." The answer was very

[1] In 2008 TiCC was started as Tilburg centre of Creative Computing. Then it was renamed as Tilburg centre of Cognition and Communication. Subsequently, it became Tilburg center for Cognition and Communication since Tilburg University adopted the American English writing style.

[2] TBDL stands for Tilburg Big Data Laboratory.

provocative for me: “I am glad you intend to study the work by Euwe and myself (Euwe, 1963) and I will be pleased to supervise you. Incidentally, your prediction is flawed.”

“The reasoning is as follows:

[Assumption]	(1)	Intuition is a vital part of chess,
[Assumption]	(2)	Grandmasters play so well because they have intuition at their disposal, and
[Proposition]	(3)	Intuition cannot be programmed, hence
[Conclusion]	(4)	Computers will never play at grandmaster level. “

There I was sitting, opposite my future supervisor, a scholar of international renown. “Excuse me, Professor, that I take the liberty to contradict you. Indeed, I do not know exactly *how* it will take place, but I believe that new technologies *will* find a solution to the problem you posed.”

1.2 The Ph.D. defence

On June 21, 1983 my Ph.D. defence took place. First, there was opposition by a colleague from the audience (about a mathematical proposition). Then Professors Herschberg, Van der Poel, Gierveld, Sciarone, and Doorman fulfilled their role as opponents. After 45 minutes the Beadle came in. It was her first Ph.D. defence as Beadle. She waved the wand before letting it go down on the floor. Rector Sikkema gestured “No, No, Not on the floor” and spoke the unprecedented words: “I extend the Ph.D. defence by 10 minutes to give Professor De Groot, who has come all the way from Schiermonnikoog, the opportunity to participate in the opposition.”

So we renewed our discussion, this time publicly: intuition, intuition and intuition again. Without intuition there could be no strong chess program. It sounded like an *obiter dictum*. Fortunately, I was well prepared and I held my positions. The audience held its breath, they saw a real clash of opinions. After the deliberation the first supervisor, Professor Lombaers, was assigned the task of awarding me the Ph.D. title and to speak the laudatio. He took no less than three quarters of an hour and outlined eloquently my research, the promotion and the future.

1.3 Intermediary

In our 10-minute dialogue Professor De Groot and I showed the public that we were evenly matched, that the discussion was interesting and that we were both convinced that we were right. De Groot, however, felt that he wrongly had not received his right from his promovendus. Six days after the promotion, I received a draft article entitled "About Chess Intuition or: the blind spot of Van den Herik" that he submitted for publication in the weekly magazine *Intermediair*. I was invited to write a short epilogue. Of course, I did so with glowing contradiction. You will, however, be surprised: my esteem for Professor De Groot rose to great heights. "What a fighter, what a chess player, what a scientist."

In 1987, Professor Marcel Fresco was our intermediary. He organised a Studium Generale in Leiden in the context of Artificial Intelligence. The two rivals were Adriaan de Groot and Jaap van den Herik. I had just been appointed professor in Maastricht, and Adriaan extended his heartfelt congratulations to me. Then the show began. I had my 10-minute presentation carefully prepared with slides and showed the latest impressive performances achieved by ChipTest (predecessor of Deep Thought, later named Deep Blue by IBM). Then it was Adriaan's turn to present his ideas. He emphasised the role of intuition and mitigated the performances by Chiptest. Subsequently the audience had to vote. According to Marcel Fresco the result was 50-50. I do not remember which of us felt wronged. Probably both. Immediately thereafter, the *pièce de résistance* followed: an hour-long debate with the public and each other on the future playing strength of machines. Afterwards, we both believed that we were able to convincingly present our arguments. After a brief break to give the audience time to reflect on what they heard, Marcel Fresco asked for a final vote. From my vantage point, I could see people in the front row voting for me instead of against, as was the case for the initial vote. The messy conduct of the voting made the outcome uncertain.

As an experienced intermediary Marcel Fresco announced the final result: it was 50-50 again. If I reflect on this moment many years later, then I believe Marcel was being kind to me. Yes, I had won some votes, but also lost some (how was that possible?). The pros and cons among the voters were completely rearranged. By recalling the audience in my mind, my estimate would be a small advantage to Adriaan. I comfort myself with the thought that at that time they did not know in Leiden the power of the looming technology, of big trees, and, of today's Big Data.

1.4 The Breakthrough

On May 11, 1997 the major (and, in my opinion expected) breakthrough took place. Deep Blue defeated world champion Garry Kasparov by a score of 3½ points to 2½. De Groot (1997) wrote an article in the daily newspaper *NRC Handelsblad*. The article was resigned, cool and aloof. The passionate fire, the one that burned brightly in the Fresco event was extinguished, even though this was the moment to reconsider his own position. After all, the fact that the human world champion was beaten by a computer program led to two possible paths.

Path 1 (Continuation of Assumption 1)
Intuition is not an essential (vital) part of chess, because a computer program without intuition was able to defeat the world champion.

Path 2 (Continuation of Assertion 3)
Intuition is a form of knowledge that we are not able to interpret correctly. Intuition is implicit in the chess knowledge that was incorporated into the program.

Since May 11, 1997 computers play stronger chess than the human world champion. The program Jonny, winner of the World Computer Chess Championships in Leiden in July 2015, is playing an estimated 400 Elo points stronger than World Champion Magnus Carlsen.

The important lesson from my interactions with Professor De Groot is as follows. Have confidence in your supervisor, even if you totally disagree with him. In 2006 Adriaan spoke similar words when my wife Letty and I paid a last visit to him on Schiermonnikoog: "We seldom agreed, we had a lovely time. That is only possible in the world of chess and in the world of science. "

2
The Start in Tilburg

On September 1, 2008 Eric Postma, Antal van den Bosch and Jaap van den Herik, along with 23 other researchers, started their new positions at Tilburg University to work on a self-imposed task, viz. to build a new research centre, called TiCC. Here I remark that Antal reunited with us from his position in Tilburg University.

2.1 The Assignment

We started as Tilburg centre of Creative Computing (TiCC). The Universiteit van Tilburg (UvT) (now called Tilburg University) expected from us the following (see also our inaugural address *Geloof in Computers* (In English: Belief and Believe in Computers), Van den Herik and Postma, 2009).

1 Strengthening humanities research in the areas of language, vision and games.
2 Strengthening and renewal, by bringing ICT contributions to education in the Humanities.
3 Reaching the peak of international research in the field of e-Humanities.

2.2 Goals Reached

After five years we had reached our goals.

A Cognition and Communication became part of TiCC.
B Van den Bosch acquired the NWO project HITIME.
C Postma acquired the NWO project REVIGO: REassessing VIncent van GOgh (via Science4Arts).
D Van den Herik and Plaat acquired as co-applicant (PI: Jos Vermaseren, Nikhef) an ERC Advanced Research Grant for the project HEPGAME.
E Creative Computing was assessed by the NVAO as follows:
Quality 5, Productivity 5, Societal relevance 5, Vitality and feasibility 4
(5 being excellent, 4 is very good).
F TiCC was recognised as a Center of Excellence at Tilburg University.
G The research culminated in 42 dissertations.

The assignment was for five years and TiCC was already performing quite well in 2013. Tilburg started specializing in Big Data research and began collaboration with Eindhoven and Den Bosch. TiCC was reinforced with Max Louwerse and has in my opinion a glorious future ahead. I am proud that I may have been the Founding Director of TiCC. I wish Emiel Krahmer, the successor of my successor Fons Maes, good luck with TiCC.

3
The Implementation

In my opinion, the core of research in general lies in guiding talented Ph.D. students. When they are performing well, then the entire institute will run well. Therefore, my attention goes out to the Ph.D. students.

3.1 The rights of a Ph.D. student

All Ph.D. students are entitled to receive much attention, good guidance, exceptional treatment, access to advanced computers, and support from an excellent organisation. The secret of a successful institute is community building, open communication, acting without hidden agendas, avoiding the use of tricks, and putting Ph.D. students always first. It sounds easy, but I assure you that it is difficult to instill this culture. The idea must be internalised.

3.2 The Ph.D. students

A step towards community building is organising an annual Ph.D. students day (the idea comes from colleague Henk Sol, then Delft University of Technology). Each student gives a presentation on their research, and everyone comments and assesses each other's work. Afterwards, the best presenter of the day is announced as such. It is a highly regarded distinction: the best among equals.

4
The stimuli by the Ph.D. students

In my university office, a visitor once looked at the row of Ph.D. theses that I had supervised so far. He said, "Have you read them all?" My answer was succinct: "Yes, every dissertation at least ten times." So it goes in science. With each reading you see something else, you have a different perspective. For Ph.D. students I sometimes go too fast, but that is because of the way they stimulate me.

4.1 Co-Supervisors

Today I wish to honour the candidates who obtained their Ph.D. during my term at Tilburg University. There are 29 of them. The Appendix contains a listing by University (Tilburg, Maastricht, Leiden). In this lecture I will focus on the 19 Ph.D. defences that were completed at Tilburg University.

With much pleasure, I thank the eight co-supervisors (the order is chronological): Eric Postma, Antal van den Bosch, Jan van Dalen, Theo de Roos, Toine Spapens, Myriam Diocaretz, Arno Arntz, and Johannes Scholtes,

and eleven daily advisors (the order is here also chronological): Karl Tuyls, Jos Uiterwijk, Guus Lange, Pieter Spronck, Nico Roos, Alfons Salden, Menno van Zaanen, Bartel Van de Walle, Mohammed Ali Wahdan, Rein Cozijn, Max Spotti, and André de Waal.

In Tilburg there were 19 Ph.D. defences, the characteristics of which were as follows:

# Men	14	# Dutch	10
# Women	5	# Non-Dutch	9

4.2 Seven Lines of Research

To set up and develop a prestigious research centre such as TiCC, excellent research is a prerequisite. After all, excellent research leads to an excellent education. Moreover, once there are some excellent students, the centre becomes more attractive for other excellent students.

For Postma and myself Social Signal Processing (SSP) topped the list of research topics within TiCC. That is also the core theme of this valedictory address. The six other topics in which I was involved within TiCC are mentioned briefly in honour of the Ph.D. students. The main line of my address is continued in Section 5.

The second line of research was Computer Science in general. Along with Postma I supervised four Ph.D. students. They were on the application of bioinformatics, cloud computing, planning, and outlier selection. The third line was, of course, computer games, my old love. Within TiCC I was supported by Pieter Spronck. The research topics were chess, video game AI, and differences in game-playing style.

Tilburg University aims at having a focus on society. This is expressed in the slogan *Understanding Society*.[3] Therefore, TiCC carried out as its fourth line of research investigations into applications of AI techniques and Knowledge Management to be used for society. Together with Maastricht School of Management (MSM) and a variety of daily advisors of Tilburg University, I was given the opportunity to supervise five Ph.D. students in this field (see list below). A second society-related topic (fifth line of research) is applying computer technology in police work. In Tilburg I was privileged to supervise three dissertations on the subject, two of them along with Theo de Roos. Moreover, in Maastricht I was encouraged by Maaike Meijer to study gender issues in conjunction with technology. That resulted in the sixth line of research in collaboration with Socrates professor Myriam Diocaretz on the topic *Engendering Technology Empowering Women*.

The seventh line of research is language. Within TiCC much investigation takes place in language research. In fact, there is a variety of linguistic topics supervised by various professors. When Antal van den Bosch invited me to join him to supervise a Ph.D. student in the field of *Statistical Language Models for Alternative Selection Sequence* I was happy to be asked. After all, with Antal I had already achieved many significant scientific results and this would add to our joint success.

The names of the researchers as well as the aforementioned research lines are classified below. Information about the Ph.D. trajectories and other supervisors is given in the Appendix.

[3] Today, the Rector Magnificus believes that Advancing Society is a better slogan.

SSP
De Croon
van der Maaten
Berezhnoy
Mattheij

Games
Reul
Bakkes
Van Lankveld

Police
Vis
De Kock
Meesters

Computer Science
Torben Nielsen
Bogaert
Mao
Janssens

KM & AI
Stol
Kakeeto
Gunawan
Marić
Bagorogoza

Gender
Pascall

Language
Stehouwer

5
Social Signal Processing

After today, I am no longer officially connected to the same university as my long-time companion Eric Postma. He was my fifth Ph.D. student, but the first one who turned my attention to the power and promises of Signal Processing, later developed into Social Signal Processing. When an Assistant Professor at the Delft University of Technology, I had learned many things in the field of medical applications through my collaboration with Eric Backer and Hans Reiber (then EUR).

5.1 Signal Processing

The title of Postma's thesis was *SCAN: A Neural Model of Covert Attention*. The thesis was about pattern recognition in ordinary images and man-made images. The research was dealing with, amongst other things, recognising images in a painting. The whole study was well-motivated, well-founded, and of high quality. Yet, I wished as a coach *after* this investigation to guide Eric into a new direction. Therefore, I suggested: "What matters is not that you recognise the image, but that you recognise the authors of the image." Eric was immediately enthusiastic: a new field of research was born. We decided to work on it in close cooperation after September 22, 1994 (his Ph.D. defence). Together we then began our scientific expedition in pattern recognition (with applications in the fields of painting) and pattern filtering from social cues. We have been supported all these years by Joke Hellemons who knew more about art than we did.

5.2 From SP to SSP

The idea of interpreting natural images or images appearing in a painting was an appealing subject for students in Maastricht. Over the years Postma and I together supervised some ten master students in this area and four doctoral students. From the four Ph.D. topics it can be seen that we have increasingly moved towards the *understanding* of images and considered the recognition of the images as a support tool for better understanding.

Here, I interrupt the course of my lecture by an enumeration. The main line is resumed in Section 6. Our learning curve as supervisors was as follows: *TheResolution of Visually Guided Behaviour* (Rens Kortman, 2003), *Situated Representation* (Michel van Dartel, 2005), *NiM: A Situated Computational Memory Model* (Joyca Lacroix, 2007)[4], *Class and Object Detection in Natural Images* (Niek Bergboer, 2007).

[4] Professor Jaap Murre was also involved in the research project as supervisor.

A very special Ph.D. project that Postma and I supervised together with Heleen Dupuis was performed at Leiden University. It was about identifying and attributing characteristics that were related to the behaviour and the physical condition of people, to arrive at recommendations to physicians when asked to make euthanasia decisions: *A Computer Model for Supporting Euthanasia Decisions* (Fred Hamburg, 2005). At the symposium which was organised in connection with the Ph.D. defence, the former leader of the Christian Union André Rouvoet gave a presentation on scientific progress in relation to government policy and thereafter Bishop (now Cardinal) Wim Eijk on scientific progress in relation to our belief in God. For Eric and myself it was a strong incentive to pay even more attention to Social Signal Processing (see Section 7).

6
Intuition

With modern technological resources, would it really be possible to make visible what you feel, what you know unconsciously? Would cameras and intelligent computer programs play a role in such a project? For example, would it be possible to interpret intuition, to explain it and define it? These were intriguing thoughts which our research generated at that time. Of course, the main reason was that Jaap still carried the legacy of Adriaan de Groot.

During my Ph.D. research I was ambitious and I wanted to write almost three dissertations. The multidisciplinary field was Computer Chess. The parts were (1) Computer Science and Artificial Intelligence, (2) Heuristics and Thinking Psychology, and (3) Philosophical Foundations upon which all these ideas were based.

For subjects (2) and (3) I had composed an extensive program of research literature and in-depth interviews. For design and development, I refer to Van den Herik (1983). Here intuition is at stake and in this area Donald Michie (1981) put me on the right track. His definition of intuition was a bridging element in the science and psychology convenant (see Subsection 6.5).

I felt that I could do something with this definition, but I had no idea how to give it a meaning. Still, the concepts, the idea and the connections were clear and almost suitable for further elaboration. I will take you on my path, which runs from Rorty, by Poincaré, Euwe and De Groot, to Michie. The main line is formed by Rorty (Subsection 6.1) and Michie (Subsection 6.5). Poincaré, Euwe, and De Groot have been important for my own scientific development.

6.1 The common definition by Rorty

In my research on intuition I focussed mainly on problem solving and on adequately formulating concepts for certain situations. According to *The Encyclopedia of Philosophy* there are four different meanings attributed to the concept of intuition. As a starting point, I then (and now again) took the common meaning, which comes from Richard Rorty (1967).[5]

[5] Of course, I am aware that the definitions given by many influential scholars on intuition are not discussed in my approach. The most well-known definitions are by: Kant, Frege, Bergson, Jung, Leibniz, Descartes, Hilbert and Brouwer.

Definition 1 (Rorty): "*Intuition is unjustified false belief not preceded by inference; in this (the commonest) sense 'an intuition' means 'a hunch'. The existence of hunches is uncontroversial and not of philosophical interest.*"

Van den Herik (1983) commented on this: "Intuition manifests itself in chess among other things as the designation of the good move without "trying" all of them. The move under inspection should lie within the human window (...). We note that the designation of the good move implies that intuition is a cognitive psychological concept in the sense of 'irrational and yet true', but does not present a way of thinking."

6.2 Intuition according to Poincaré

Poincaré (1913, p. 381) notes that not everyone can have some form of intuition. This fits in with De Groot's ideas: intuition is for the happy few, the chess grandmaster. As an illustration, we provide below a relevant quote by Poincaré.[6]

"We know that this feeling, this intuition of mathematical order, that makes us *divine* hidden harmonies and relations, cannot be possessed by everyone. Some will not have either this delicate feeling so difficult to define, or a *strength of memory* and attention beyond the ordinary, and then they will be absolutely incapable of understanding higher mathematics. Such are the majority. Others will have the feeling only in a slight degree, but they will be gifted with an *uncommon memory* and a great power of attention. They will learn by heart the details one after another; they can understand mathematics and sometimes make applications, but they cannot create. Others, finally, will possess in a lesser or greater degree the special intuition referred to, and then not only can they understand mathematics even if their *memory is nothing extraordinary*, but they may become creators and try to invent with more or less success, according as this intuition is more or less developed in them." [emphasis added by vdH]

6.3 Intuition according to Euwe

More than half a century later, chess grandmaster and former World Champion Max Euwe expressed the same thoughts for chess as did Poincaré for mathematics. Euwe (1964) did so in his inaugural address at the Catholic University of Tilburg.

[6] The emphasis is added by vdH. It was impossible to consult the original French text. Several publications by Poincaré are directly translated from his French manuscript into English.

> "The essential element of playing chess at a high level is *inspiration*. The skill competence of a chess player is based on a multitude of factors, such as directly accessible knowledge, memory, accuracy, ability for combinations, but especially on consolidated experience. De Groot considers the latter as indicative for the distinction between master and non-master. Yet, there are chess masters who (in brief) know everything and see everything and still never will succeed in reaching the highest echelons. It is said that they do not have sufficient imagination. It is thought that these players do not have from time to time a lucid thought, say a *hunch*." [Emphasis added by vdH]

On June 10, 1980, we discussed this passage on a lucid thought. Can players without having once in a while a lucid thought nevertheless become a strong chess-player? Euwe was succinct:
"…. According to my statement then, the answer is no and I still stick to that answer. "

At the time, Van den Herik (1983, p. 473) commented on this passage as follows. "By this statement Euwe emphasises that computer programs in his view, would never play strong, because a computer will never get a hunch and therefore does not play excellent moves."

In brief, Euwe felt that a hunch was not programmable. I assume by this statement "that for Euwe inspiration means: A happy or lucid thought which can give a decisive turn to the game" (Van den Herik, 1983, p. 473).

6.4 Intuition according to De Groot

Adriaan de Groot can be seen as the "grandmaster" of intuition, at least when it comes to chess. He defines the term as follows.

Definition 2 (De Groot): "*Intuition is having judgements (or making decisions) in a manner that cannot be made explicit.*"

In my thesis, this statement is discussed deeply (Van den Herik, 1983, pp. 472-491). Here I confine myself to two points.
De Groot (1965, pp. 308-309) argues that intuition is not irrational, but it still cannot be implemented in program form as a chess player cannot explain intuition itself.

De Groot (1965, pp. 309-310) believes that intuition is not infallible, but it generally ensures a reasonable degree of correctness.

Here, I note that I agree with De Groot that (A) intuition is not irrational and (B) intuition is not infallible (and generates a reasonable degree of correctness). However, I had a dispute with him on the point that intuition cannot be programmed.

6.5 Intuition according to Michie

In an in-depth interview with Donald Michie (April 10, 1981, see Van den Herik, 1983, pp. 563-578), a new perspective on intuition was presented. Michie's definition is as follows.

Definition 3 (Michie): "*Intuition is simply a name for rule-based behaviour where the rules are not accessible for consciousness.*"

We note that both the definition by De Groot and that by Michie concur with the common definition by Rorty. However, the definitions by De Groot and Michie themselves are substantially different. Michie does not make a statement on the correctness of intuitive judgement.

7
The Place of Intuition

So far we have concentrated on mental intuition with the emphasis on intuition as an element in solving problems. Intuition is, however, a much broader concept. On the site www.encyclo.nl/begrip/intuitie there are twenty definitions of the concept intuition. That is too many for today. In addition, it leads to additional difficulties in the classification of common themes. I therefore start from the following four forms of intuition:

- Mental intuition,
- Physical intuition,
- Emotional intuition, and
- Environmental intuition.

Below, I will classify (a) spiritual intuition as emotional intuition, and (b) inspiration (see Euwe) as mental intuition. In a footnote in Subsection 6.1 I mentioned already eight researchers who have been dealing with intuition. They usually mention Thinking (T), Sensing (S), Feeling (F) and iNtuiting (N). All researchers find it difficult to grasp the concept of intuition in sufficient detail. It is therefore remarkable that two practical investigators without special training in this direction have proposed a model that has received many followers (mostly human resource people). It is the model MBTI (Myers-Briggs Type Indicator). Mother Myers and daughter Briggs have relied on the theory developed by Carl Gustav Jung (1921). Jung distinguished two directions: (1) Rational: Thinking or Sensing and (2) Irrational: Feeling or Intuiting. Later the direction (3) Introvert or Extrovert was added to the discussion on intuition. Thereafter the fourth direction (4) Judging or Perceiving was added in the MBTI model. It is generally known that there is neither a scientific basis for Jung's work nor for the work by Myers and Briggs (see, e.g., nl.wikipedia.org/wiki/Myers-Briggs_Type_Indicator). In addition, I would like to remark that the work by Myers-Briggs is not consistent with the evidence-based Big Five personality dimensions (see Wiggings, 1996). Promotus Giel van Lankveld (2013) focussed on the Big Five, but did not address the differences with Myers-Briggs. A few interesting but otherwise differently coloured ideas about intuition were echoed by Henk Barendregt (2015). In his farewell speech he examined the keys to two intimate feelings based on Mathesis and Mysticism. He did so by adding the personal and non-personal. In this address I have endeavoured to find a more "down to earth" approach.

Through my sparring partner Hans Konstapel[7], I arrived at the theory by Will McWhinney (1984).

7.1 The Model by McWhinney

In his fascinating publication *Grammars of Engagement* Will McWhinney covers several different perspectives that we can have on the world. His constructions consist mainly of four elements, which pairwise have a relationship. To give you an idea I reproduce in Table 1, *A Variety of Models That Use Four Similar Modes* (in Grammars of Engagement, Figure 3.4).

THE FOUR MODES					
SOURCE	DETERMINED		VOLUNTARISTIC		REFERENCES & COMMENTS
Four Realities	Unitary	Sensory	Social	Mythic	McWhinney (1984).
Buddhist	Samjña	Rupa	Vedana	Samskara	Conze (1951).
Plato	Reason	Understanding	Opinion (faith)	Perception of Shadows	Jowett's terms from The Republic and Gilbert Ryle (1967).
Gospels	Matthew (Lion)	Mark (Ox)	Luke (Man)	John Eagle)	The parallels were observed and analyzed by John Lai (1996). The metaphors are from Revelation, 4:7.
Lakota Indian	North (Buffalo)	South (Mouse)	West (Bear)	East (Eagle)	Storm (1972) writing from a Plains Indian worldview.
Jung	Thinking	Sensing	Feeling	Intuiting	Jung's Personality Types (1920).
LeShan	Clairvoyant	Sensory	Transpsychic	Mythic	Lawrence LeShan (1976). Descriptions of exceptional people.
Hermann	Left Cerebral	Left Limbic	Right Limbic	Right Cerebral	Ned Hermann (1989).
Latour	Being	External Reality	Social Bond	Signification and Meaning	Bruno Latour (1991).

Table 1: *Nine Models with Four Similar Modes.*

7.2 The Model Focussing on Intuition

The ideas by McWhinney published in *Grammars of Engagement* bring us back to Jung (see Table 1). After all, Jung is the only contributor who called intuition by the name Intuiting in Table 1. Yet, we see that in this column there are also other ideas, such as *Right Cerebral* (Hermann, 1989) and *Signification and Meaning* (Latour, 1991). These ideas led intuition away from the stamp "irrational" which by some (not De Groot and Euwe) is now and then given to intuition.

[7] For many years Hans Konstapel and I were advising Leen Zevenbergen and later on Berry Veldhoen (Bolesian). Konstapel then was leading the Department of Innovation of Automatisation at ABN AMRO.

To stimulate the mind, I propose below a simple model of possible connections. The "mind" model consists of four components, namely T (Thinking), S (Sensing), F (Feeling) and N (iNtuiting). As so often, the essence does not lie in modelling the components *per se*, but it lies in the connections and their substantiations. For now I only discuss four mutual connections, namely T ↔ S, S ↔ F, F ↔ N, N ↔ T. In the literature you will find many descriptions and explanations of these links. In Figure 1, each connection is personalised by a person earlier mentioned in this address. I leave the interpretation of the names assigned to the connections to the audience/readership.

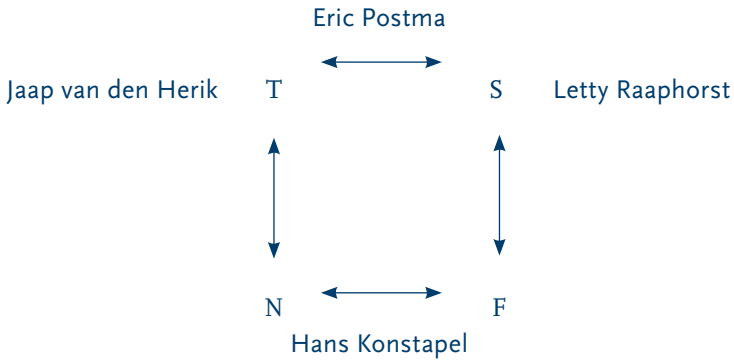

Figure 1: An Instantiation of the *Four Modes*

N (Intuition) has also some relation with imagination. One of the most inspirational figures in the area of imagination is Leibniz. As is well known, his approach to mathematics and physics was rather different from that of Newton. Leibniz was a Renaissance man who was driven by the question: how can we imagine what is interesting? As Konstapel told me: "In the Renaissance period researchers can be best characterised as persons who looked through a very narrow opening ("peephole") in order to understand the genesis of the 'perspective'." This is probably the way we nowadays look at a former generation of researchers dealing with intuition. For the current researchers, the prevailing question is whether there exists a design for programming intuition.

8
From De Croon to Mattheij

The research in the area of Pattern Recognition, that started with Rens Kortmann, Michel van Dartel, Joyca Lacroix and Niek Bergboer (see Section 6) was continued by Guido de Croon. He examined the straightforward question: How do adaptive active vision models handle challenging visual tasks? What he did not know (and also not his supervisors) was that his research was well suited for controlling drones. In this speech, however, I consider his results only as a step towards the implementation of intuition.

8.1 Adaptive Active Vision

Around 1980, the area of vision investigation was dominated by passive Computer Vision Systems (cf. Marr, 1982). Some ten years later, the idea emerged that active foveal vision systems could have major benefits. The reason is that such a system would be able to process a foveal portion of the visual picture with high resolution (cf. Ballard, 1991). Two immediate advantages were: (1) the simplification of relevant tasks by the introduction of actions, and (2) the reduction of computational operations, because only a portion had to be treated.

Soon evolutionary algorithms were introduced to provide robots with an action strategy for performing their duties. This resulted in several optimisation algorithms; adapting a strategy to the tasks to be carried out played an important role. It even became a research domain of its own right, viz. that of *Coevolution of Active Vision and Feature Selection* (cf. Floreano et al., 2004). When De Croon began his research he saw three open issues, namely (1) it was uncertain whether adaptive active vision models could successfully be applied to difficult tasks in computer vision, (2) until then the researchers did not understand exactly how adaptive active vision worked, and (3) it was unclear what effect adaptive active vision would have in a control task? The adaptive approach led to the surprising insight that virtual eye movements can serve not only to gather information, but also (a) to avoid disturbing visual observations, and (b) to use the environment as external memory to maximize the job-specific information in the observations.

8.2 Dimension Reduction

The study by De Croon was followed by excellent results achieved by Laurens van der Maaten (2009) on *Feature Extraction from Visual Data*. His work was awarded with the judicium cum laude.[8] The thesis is a technical dissertation on

[8] Of the 71 theses I delivered two promoti with this judicium; the other thesis was by Antal van den Bosch (1997).

dimension reduction. Laurens has worked as part of his thesis with Geoffrey Hinton, who was then a professor at the University of Toronto. Together with Hinton, Laurens has developed a dimension reduction method which is currently used worldwide. The previously unpublished internal survey of dimension reduction methods is the most quoted output result of the three of us (van der Maaten, Postma and van den Herik, 2009, 361 citations).

The scientific triad (active vision - dimension reduction - deep learning) became transparent for Eric and me around 1995. At that time neural investigations by Geoffrey Hinton and his colleague Yan LeCun, inspired us to investigate automatic pattern recognition. Patrick Hudson initiated the first contact and Laurens made the connection to the point by realising what Eric and myself had developed in an elementary way. Now, twenty years later, Hinton and LeCun form the core of the deep learning revolution (LeCun, Bengio, and Hinton, 2015). Hinton is currently working part-time for Google and LeCun is Director of the AI research laboratory of Facebook. Laurens is one of his assistants. With deep learning many successes are being achieved in the field of pattern recognition, but there are not yet applications in the direction of intuition. That will be done by the successors of Ruud Mattheij.

Pattern recognition was also the theme of the thesis by Igor Berezhnoy (2009) entitled *Digital Analysis of Paintings*. Berezhnoy's third research question is: Are there any visual features that serve as fingerprints of the author and may reveal his identity independently of his style or the painted subject? This comes close to recognising intuitive expressions in art. However, it is still different from creating intuitive expressions. Nevertheless, the key to progress is in this study. The idea is that after recognition the researcher may save results for future use. The stored results can then be used to generate intuitive expressions (say, create intuitive facial or behavioural expressions).

In this specific domain of research our cooperation with the TU/e played a very important role. Around 2007 the group led by Cees Midden (TU/e) began to develop new techniques for autonomous systems in order to convince ordinary people that they (1) should use less energy than they are using and (2) should store unused energy. It was an ambitious project in which technological and psychological knowledge were needed to create a successful interaction between people (users) and agents (computer programs that give wise guidance - the

agents are also known as embodied agents). It was a challenging project, where it soon became clear that the main obstacle was in personalised feedback that was socially acceptable. Thus in 2010 Midden & Ham (TU/e) and Postma & Van den Herik (Tilburg University) composed and wrote a new project proposal entitled *Persuasive Agents* in which feedback was central, i.e., to understand what drives the other companion, in other words, the issue is understanding non-verbal communication. The project was awarded in late 2010.

8.3 Through the Looking Glass

In 2011 Ruud Mattheij was appointed as Ph.D. student to conduct the above challenging research project. The entire group of investigations consisted of researchers from Informatics (Tilburg)[9] and Psychology (Eindhoven)[10], as well as practitioners from Smart Homes Foundation[11]. Below I provide a description of the research mainly on the basis of images with associated text.

Figure 2: Interaction between man and embodied agent

Figure 2[12] shows how an embodied agent tries to convince a "member of the household" that he would have to use less water. Personalised feedback asks for subtle facial expressions (sad or angry, if too much water is used). But more importantly for the embodied agent is recognising (a) the facial expressions of the member of the household, and (b) preferably also his intuitive feelings. In

[9] https://www.tilburguniversity.edu/research/institutes-and-research-groups/ticc

[10] http://www.tue.nl/universiteit/faculteiten/industrial-engineering-innovation-sciences/onderzoek/onderzoeksgroepen/human-technology-interaction

[11] http://www.smart-homes.nl

[12] Adopted from Mattheij (2016).

the following, I will use Eric Postma (in text and pictures) as an example of a household member. The problem statement of Mattheij's Ph.D. thesis reads: To what extent is it possible to detect body parts and behaviour when using in-depth information?

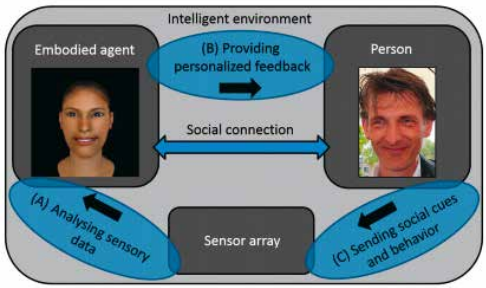

Figure 3: *Four research tasks*

In Figure 3[13], the work plan of the problem statement is described as follows:
A analysing the output of the sensor array,
B formulating personified feedback,
C storing Eric's behaviour (social cues and behaviours), and
D filling of the precise roles of the sensor array.

Mattheij first studied The Microsoft Kinect device (see, e.g., Smisek et al., 2013). The Kinect device generates depth images by (1) reducing the spatial area with an infrared laser and (2) triangulating of the corresponding depth with the infrared sensor results. The depth images have a resolution of 640x480 pixels. Shotton et al. (2013a,b; 2011) used the Kinect for recording the depth-orientation of the body parts by capturing the individual pixel location in single-depth images. A detailed description is in Shotton et al. (2013a,b; 2011). An insightful summary is in Mattheij (2016). The essence is that Shotton et al. emphasise the pixel-based comparisons.

Mattheij's idea is to use proper sensor images for region-based comparison and not for pixel-based comparison. In his thesis he offers arguments and demonstrates the strength of RC (Region-based Components) compared to PC (Pixel-based Components) convincingly in three experiments (see Mattheij, 2016).

[13] Adopted from mattheij (2016).

The RC-characteristics are highly relevant to the development of embodied agents which are intended to capture accurately the natural interactions with humans, and then to use the results in their conversation.

To accomplish these two tasks the detectors should be trained (by the region-based comparison detector) to interpret the deep data that contain spontaneous human behaviour and unconscious intuitive behaviour, to interpret them appropriately and then store the behaviours. So far, however, no databases are available in the public domain that contain thorough annotated depth images of people making spontaneous gestures, let alone of people exhibiting intuitive behaviours.

For this purpose Ruud Mattheij has developed an annotated database called STAGE. There, the visual representations with the depth data of human gestures and facial expressions are saved. Mattheij subsequently examined to what extent people's verbal and non-verbal expressions appearing in an embodied agent were mimicked by the embodied agents. His results are based on an embodied agent with a human appearance (see Figure 2) communicating verbally and nonverbally.

The procedure is partitioned into three types of registration: (1) the changes in the pitch of the voice, (2) the changes in the speed of speaking, and (3) the difference in facial expressions that caused the changes. It appears that small localised changes of behaviour in the visual and auditory domain lead to (a) significant changes in human facial expressions and (b) detectable changes in the vocal behaviour. Often the intuitive behaviour changes. The results therefore imply that people react to embodied agents (with whom they are familiar) as ordinary interlocutors. Based on these observations Mattheij concludes that people can have a social relationship with embodied agents who are similar to human beings.

In Figure 4[14] we see four blocks in the sensor array, with results from Mattheij's research (research task D). They are:
(1) a detector which can compare the regions (instead of pixels) with each other,
(2) a sensor that can observe rather deep layers,
(3) a detector that can search the database (STAGE), and
(4) a set of features which are region-based.

[14] Adopted from Mattheij (2016).

The detector compares these regions with each other and uses the sensor which can detect images at deep layers by looking through a very narrow opening ("peephole"). In this way the intuitive perspective as attributed to Leibniz (see Subsection 7.2) becomes a reality in the form of seeing "through the looking glass".

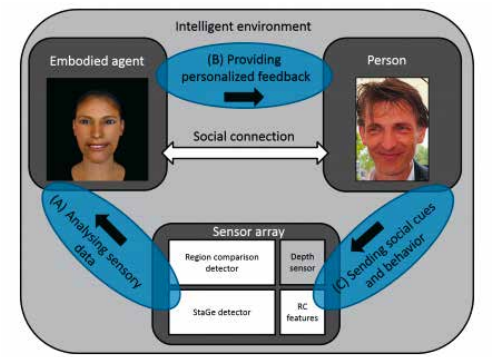

Figure 4: *Four tangible results of research task D.*

8.4 My Claim

For recognising paintings (see, e.g., Berezhnoy, 2009) we have seen that success is based on recognition of (1) the brush stroke, (2) the composition, and (3) the colour combination. Minimal differences can lead to different answers. The storage of these features resulted in a database which basically contains all the characteristics of a painter (e.g., Van Gogh). From these characteristics a suitable program can then compose a "new" Van Gogh. The new painting is a "perfect" Van Gogh. Possibly only seasoned experts may see that it is *not* a true Van Gogh, because Van Gogh was a human being who is gifted by nature to make small mistakes towards his own style; a computer program does not.

What is true in painting has already taken place in the world of music composers. There are compositions in Bach's and Mozart's style that are composed by a computer program (Cope, 2000, 2008). To streamline the procedure Cope has developed four tools: *Liquid Notes, Quartet Generator, Easy Music Composer* and *Maestro Genesis*. To obtain a clear picture of what is going on in the world of music composition by computer, I refer the reader to engineersonline.nl (2015). The

title alone will make you realise that the developments are changing fast, *The computer as a composer: the high-tech answer to Mozart* (March 17).

All in all, it is clear that AI developments in painting and music composition put us on the right track. Moreover, Louwerse et al. (2012) have already shown that matching of behaviours in multimodal communication occurs in a synchronized way. If we can also save the human behaviours (as in STAGE) and if we can register intuitive decisions and indicate them, then it should be possible to obtain the intuitive considerations hidden in all available data. Consequently, a programmer may make those identified intuitions accessible in computer program formulations that fit other components in the overall program. It is similar to genetic engineering, where researchers are also involved in identifying genes that cause serious afflictions.

To summarise, I am convinced that we can take elements from registered intuitive behaviours, which we can then implement as program blocks in the AI programs of the future. It means nothing more and nothing less than that intuition can be programmed.

9
Conclusion: Science Lives by Contradiction

I started my valedictory address by a tribute to my mentor Adriaan de Groot. He has shown me the right path. However, his erudite words asked for contradiction.

Contradiction and setback are gifts of the rational thought processes. How can I deal with a difference of opinion? How do I fix this? Contradiction and setback lead to values that are formative for your entire life.

My conclusion is therefore that the best results come from studies where a doctoral student and the supervisor disagree on a relevant part of the research. In my inaugural speech in Maastricht (Van den Herik, 1988), I thanked my supervisor Joop Doorman for his opposition to many of my ideas with the words: *Du choc des opinions jaillit la verité!*

I hope that I am still given to supervise many future Ph.D. students.

10
Words of Appreciation

At the end of this valedictory address, I consider it a real privilege to pronounce words of gratitude. The list could be long but I will confine myself to the main characters in my Tilburg life. First of all, I would like to thank Frank van der Duyn Schouten, Hein van Oorschot and Arie de Ruijter who gave me the opportunity to build up so much in Tilburg with my Maastricht team. I could do this with the cooperation of many. From them I single out Eric Postma, Antal van den Bosch and Joke Hellemons. Of course, I thank my Ph.D. students mentioned by name in the printed version of this address. I also thank the current Tilburg University authorities, Emile Aarts and Koen Becking. I would like to thank Emile in particular for his supportive attitude towards the NWO program Catch, and Koen for the same attitude towards TBDL.

In earlier inaugural and valedictory addresses, I thanked my parents, wife and daughters for their presence in my life. The loss of my parents is supplemented in a natural way by sons-in-law and grandchildren. Gabe, Rosa, Julia, Mercedes, Lucero, Nika, Steffi and Manou, you heard it right. Grandpa loves contradiction. Take this statement along with you in your life, but never forget to obey the corresponding politeness.

I put down the word.
As you know, this is the real translation of

Dixi.[15,16,17]

[15] Bob Herschberg taught me to translate dixi by "I put down the word" or "I am done with speaking". It is an action in the present time, not in the present perfect. Therefore, the translation "I have spoken" is not the precise translation of dixi on this place.

[16] I am grateful to David Levy, Jonathan Schaeffer, Erik Schultes and Katy Wolstencroft for their comments on earlier versions of this valedictory address.

[17] The valedictory address is available online at http://www.universiteitleiden.nl/en/news/2016/01/jaap-van-den-herik-intuition-is-programmable.

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Appendix

Ph.D. students (co-)supervised by H. Jaap van den Herik in the period from September 1, 2008 to January 1, 2016 in Tilburg.

Tilburg University

1) Ph.D. Student : B. Torben-Nielsen
   Title : Dendritic morphology: function shapes morphology
   Date : 3 December 2008
   University : Tilburg University
   Supervisors : Prof.dr. H.J. van den Herik, Prof.dr. E.O. Postma
   Daily advisor : Dr. K.P. Tuyls

2) Ph.D. Student : H.R. Stol
   Title : A framework for evidence-based policy making using IT
   Date : 21 January 2009
   University : Tilburg University
   Supervisor : Prof.dr. H.J. van den Herik

3) Ph.D. Student : F. Reul
   Title : New Architectures in Computer Chess
   Date : 17 June 2009
   University : Tilburg University
   Supervisor : Prof.dr. H.J. van den Herik
   Daily Advisor : Dr. J.W.H.M. Uiterwijk

4) Ph.D. Student : L.J.P. van der Maaten (cum laude)
   Title : Feature Extraction from Visual Data
   Date : 23 June 2009
   University : Tilburg University
   Supervisors : Prof.dr. E.O. Postma, Prof.dr. H.J. van den Herik
   Daily Advisor : Dr. A.G. Lange

5) Ph.D. Student : I. Berezhnoy
   Title : Digital Analysis of Paintings
   Date : 7 December 2009
   University : Tilburg University
   Supervisors : Prof.dr. E.O. Postma, Prof. dr. H.J. van den Herik

6) Ph.D. Student : S.C.J. Bakkes
Title : Rapid Adaption of Video Game AI
Date : 3 March 2010
University : Tilburg University
Supervisor : Prof.dr. H.J. van den Herik
Daily Advisor : Dr.ir. P.H.M. Spronck

7) Ph.D. Student : B. Bogaert
Title : Cloud Content Contention
Date : 30 March 2011
University : Tilburg University
Supervisors : Prof.dr. H.J. van den Herik, Prof.dr. E.O. Postma

8) Ph.D. Student : X. Mao
Title : Airport under Control
Date : 25 May 2011
University : Tilburg University
Supervisors : Prof.dr. H.J. van den Herik, Prof.dr. E.O. Postma
Daily Advisors : Dr. N. Roos, Dr. A. Salden

9) Ph.D. Student : J.H. Stehouwer
Title : Statistical Language Models for Alternative Sequence Selection
Date : 7 December 2011
University : Tilburg University
Supervisors : Prof.dr. A.P.J. van den Bosch, Prof.dr. H.J. van den Herik
Daily Advisor : Dr. M.M. van Zaanen

10) Ph.D. Student : N.T. Kakeeto-Aelen
Title : Relationship Marketing of SMEs in Uganda
Date : 1 February 2012
University : Tilburg University
Supervisors : Prof.dr. J. Chr. van Dalen, Prof.dr. H.J. van den Herik
Daily Advisor : Dr. B.A. Van de Walle

11) Ph.D. Student : T. Vis
Title : Intelligence, politie en veiligheidsdienst: verenigbare grootheden?
Date : 6 June 2012
University : Tilburg University
Supervisors : Prof.mr. Th.A. de Roos, Prof.dr. H.J. van den Herik, Prof.dr. A.C.M. Spapens

12) Ph.D. Student : N.A. Pascall
Title : Engendering Technology Empowering Women
Date : 19 November 2012
University : Tilburg University
Supervisors : Prof. dr. H. J. van den Herik, Prof. dr. M. Diocaretz

13) Ph.D. Student : A. Gunawan
Title : Information Access for SMEs in Indonesia
Date : 19 December 2012
University : Tilburg University
Supervisors : Prof. dr. H.J. van den Herik
Daily advisors : Dr. M.A. Wahdan, Dr. B.A. Van de Walle

14) Ph.D. Student : G. van Lankveld
Title : Quantifying Individual Player Differences
Date : 27 February 2013
University : Tilburg University
Supervisors : Prof. dr. H.J. van den Herik, Prof.dr. A.R. Arntz
Daily advisor : Dr.ir. P.H.M. Spronck

15) Ph.D. Student : J.H.M. Janssens
Title : Outlier Selection and One-Class Classification
Date : 11 June 2013
University : Tilburg University
Supervisors : Prof.dr. E.O. Postma, Prof. dr. H.J. van den Herik

16) Ph.D. Student : P.A.M.G. de Kock
Title : Anticipating Criminal Behavior.
Date : 10 September 2014
University : Tilburg University
Supervisors : Prof. dr. H.J. van den Herik, Prof.dr. J. Scholtes
Daily advisor : Dr.ir. P.H.M. Spronck

17) Ph.D. Student : J. Mari
Title : Web Communities, Immigration, and Social Capital.
Date : 18 November 2014
University : Tilburg University
Supervisor : Prof. dr. H.J. van den Herik
Daily advisors : Dr. R. Cozijn, Dr. M. Spotti

18) Ph.D. Student : P.M.A. Meesters
Title : Intelligent Blauw
Date : 1 December 2014
University : Tilburg University
Supervisors : Prof. dr. H.J. van den Herik, Prof.dr. T.A. de Roos

19) Ph.D. Student : J. Kyogabiirwe Bagorogoza
Title : Knowledge Management and High Performance
Date : 24 November 2015
University : Tilburg University
Supervisor : Prof. dr. H.J. van den Herik
Daily advisors : Dr. A. de Waal, Dr. B.A. Van de Walle

Maastricht University

20) Ph.D. Student : L.M.M. Braun
Title : Pro-active Medical Information Retrieval
Date : 29 October 2008
University : Maastricht University
Supervisors : Prof.dr. H.J. van den Herik, Prof.dr.ir. A. Hasman

21) PH.D.Student : S. de Jong
Title : Fairness in Multi-Agent Systems
Date : 4 June, 2009
University : Maastricht University
Supervisors : Prof.dr. H.J. van den Herik, Prof.dr. E.O. Postma
Daily Advisor : Dr. K.P. Tuyls

22) Ph.D. Student : S. Vanderlooy
Title : Ranking and Reliable Classification
Date : 1 July 2009
University : Maastricht University
Supervisors : Prof.dr. H.J. van den Herik, Prof.mr. Th.A. de Roos, Prof.dr. E. Hüllermeier

23) Ph.D. Student : A.A. Latoszek-Berendsen
Title : Intention-based Decision Support. A new way of representing and implementing clinical guidelines in a Decision Support Sytem.
Date : 26 September 2013
University : Maastricht University
Supervisors : Prof. dr. A. Hasman, Prof. dr. A.P.M. Gorgels, Prof. dr. H.J. van den Herik

Leiden University

24) Ph.D. Student : W.I. Koelewijn
Title : Privacy en Politiegegevens. Over geautomatiseerde informatie-uitwisseling.
Date : 4 November 2009
University : Leiden University
Supervisors : Prof.dr. H.J. van den Herik, Prof. mr. A.H.J. Schmidt
Daily Advisor : Dr. L. Mommers

25) Ph.D. Student : H.H. Kielman
Title : Politiële gegevensverwerking en Privacy, Naar een effective waarborging
Date : 14 April 2010
University : Leiden University
Supervisors : Prof.dr. H.J. van den Herik, Prof.mr. A.H.J. Schmidt
Daily Advisor : Dr. L. Mommers

26) Ph.D. Student : K. Siewicz
Title : Towards an Improved Regulatory Framework of Free Software.
Date : 20 April 2010
University : Leiden University
Supervisors : Prof.dr. H.J. van den Herik, Prof.mr. A.H.J. Schmidt

27) Ph.D. Student : R.Y.C. Ong
Title : Mobile Communication and the Protection of Children
Date : 22 April 2010
University : Leiden University
Supervisor : Prof.dr. H.J. van den Herik
Daily Advisor : Mr.dr. B. Schermer

28) Ph.D. Student : M. Voulon
Title : Automatisch contracteren
Date : 3 June 2010
University : Leiden University
Supervisors : Prof.dr. H. Franken, Prof.dr. H.J. van den Herik

29) Ph.D. Student : J. Gard
Title : Corporate Venture Management in SMEs
Date : 2 December 2015
University : Leiden University
Supervisors : Prof. dr. B.R. Katzy, Prof. dr. H.J. van den Herik, Prof.dr.G.H. Baltes

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graphic design
Beelenkamp ontwerpers, Tilburg
cover photography
Maurice van den Bosch
print
PrismaPrint, Tilburg University