A compass towards equity: a data analysis framework to capture children's behaviour in the playground context

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CHAPTER 1

General Introduction

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1.1 Background

The rapid growth of technology in wearable devices, such as smartphones and smartwatches, has created huge amounts of data. The availability of wearable data has impacted our daily lives in different ways. We might not have been interested in physiological metrics such as step counts or heart rate a few years ago, but now, many people regularly check health applications on their smartphones to track these measures. We have become our personal data experts, looking at a bar chart and figuring out why we walked more some days than others. Yet, the use of data is not limited only to personal applications. The availability of wearable data creates various possibilities for us and society to address fundamental challenges.

This is particularly evident in micro-communities, i.e., small, localized groups of individuals with common interests, such as athletes in sports clubs, the elderly in nursing homes, and children in playgrounds. In sports clubs, for example, athletes use wearable technology to analyze their sports resilience [10]. In nursing homes, wearable data captures elderly conditions, such as detecting fall behavior [11]. Similarly, children's physical activity levels in playgrounds can be registered through wearable data to assess their physical health condition [12].

Besides individual physical health applications, micro-communities might also be beneficial in other areas. From a psychological point of view, micro-communities provide opportunities for socialization, forming friendships, and feeling a sense of belonging [13–15]. Yet, micro-communities may include barriers that hinder individuals' social and physical development [16–18]. Thus, collecting and processing data from these communities could play a key role in addressing these barriers and creating a positive environment that promotes equity among all children.

From the perspective of data science, the challenge is how to effectively collect, process, and interpret data from individuals in micro-communities as objectively and comprehensively as possible and derive meaningful insights. The obtained knowledge can facilitate various stakeholders, such as schools, psychologists, architects, and policymakers, to address fundamental challenges in micro-communities.

1.1.1 Children in Playgrounds

Children in playgrounds, as an instance of a micro-community, is particularly interesting. In playgrounds, children develop their social skills through play and socializing [19, 20], and enhance their physical skills by engaging in different active games [21–23]. Yet, playgrounds may contain unexpected barriers that hinder children's social and physical development, particularly for those with communication difficulties, such as children with cochlear implants or autistic children. For

instance, several studies reported higher sensory sensitivities perceived by autistic children [24–26]. This higher level of sensitivity can increase discomfort in autistic children in noisy and unstructured environments. As a result, crowded areas around popular play structures in playgrounds might overwhelm autistic children and exclude them from interacting with their peer groups. This exclusion can result in loneliness, which ultimately affects children's quality of life [27–29]. Playgrounds should become environments where all children feel welcome, accepted, and included.

Creating such an environment starts with understanding children's capacities and needs, on the one hand, and identifying playgrounds' limitations and possibilities, on the other hand. Hereby, the challenge becomes how to collect, process, and interpret data from children (on an interpersonal level) and their interactions with playground environments (on environmental levels) to obtain this understanding as accurately as possible. Our understanding of playground dynamics, including interactions with the design features, peer groups, and cultural constraints, provides valuable knowledge for various stakeholders, such as schools, designers, and policymakers, to address fundamental challenges and limitations in playgrounds.

1.2 Playground Analysis Framework

To achieve this, there is a need to develop a data analysis framework that can examine individuals' behaviors at interpersonal (i.e., children) and environmental (i.e., playground) levels. This data analysis framework addresses differences in individual needs in playgrounds, which serves as a compass for equity in the playground context. To design such a framework, we first need to understand the characteristics of playgrounds, especially those that might introduce unique challenges to our data analysis framework. For this purpose, the three characteristics of playgrounds are identified as follows:

- *Multiple Environments.* Children are not isolated in playgrounds. Instead, they constantly interact with multiple environments, including the physical design (e.g., play structures, layout, and materials in playgrounds), peer groups (e.g., interactions with peers), and local rules and constraints (e.g., restrictions on the use of certain areas). Our framework must comprehensively and unobtrusively incorporate these environments surrounding children.
- *Individual Experiences.* Capturing children's actual behaviors in playgrounds and identifying their social networks does not tell us how they feel or what they want. For example, as an outsider, we might interpret a child's experience who is sitting on their own differently from what that child is experiencing.

Thus, another crucial element is understanding individual differences in their personal perspectives and experiences. These individual differences must accurately and unbiasedly be included in our framework.

- *Spatio-temporal Dynamics.* Children often participate in various activities across different areas in playgrounds. For example, a child might spend the first few minutes playing with swings, then join a group to play soccer, and then walk on their own in the last minutes of recess time. A record of these dynamic changes, both spatially and temporally, should be consistently assessed in our framework to make an accurate picture of a playground.

To address these unique characteristics, our analysis framework should include a data acquisition tool that captures individuals' interactions within multiple environments in playgrounds over time and space, coupled with their experiences. Additionally, the analysis framework should be able to process and interpret such multidimensional data to create understandings and insights of limitations and possibilities in playgrounds. Providing this knowledge enables us to propose practical interventions to address the limitations and promote equity for all children.

1.3 This Thesis

The main goal of this thesis is to develop a framework for analyzing children's behavior in playgrounds. The proposed framework has addressed the three main characteristics of playgrounds, i.e., multiple environments, individual experiences, and spatio-temporal dynamics, as depicted in Figure 1.1, as follows:

Feature 1. Multiple Environments.

The primary step in designing the analysis framework is identifying environments that may impact children's behavior and experiences. This exploratory phase enables us to define essential variables for capturing the identified environments and choose proper data acquisition tools to measure the defined variables. In fact, the foundation of the analysis framework lies in a data acquisition methodology to comprehensively, unobtrusively, and consistently collect data from children's behavior in multiple environments. Previous studies often relied on qualitative data such as observations and self-reports [30–32]. However, these methods are not capable of effectively capturing all contributing elements over recess time. To address this, some studies have utilized sensing technologies, e.g., wearables, to examine one specific behavior, such as examining physical activity levels [33, 34] or face-to-face contacts [7, 35, 36]. Yet, a gap remains in designing a data-driven approach based on sensors to collectively capture children's behavior in all related environments

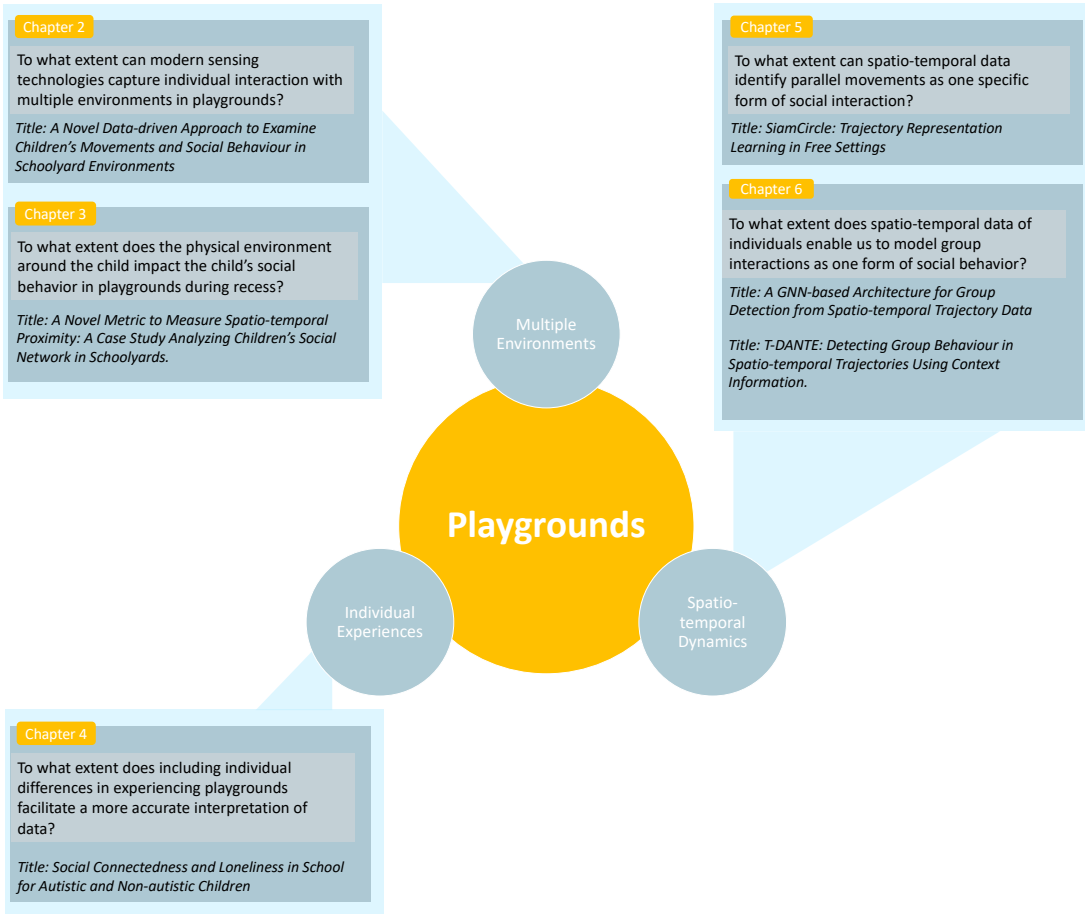

Figure 1.1: An overview of characteristics of playgrounds including (1) Interconnected Environments, (2) Individual Experiences, and (3) Spatio-Temporal Dynamics, that pose challenges to our data analysis framework.

surrounding them over recess time in playgrounds. Therefore, the first research question of this dissertation is:

RQ. 1. (Chapter 2): To what extent can modern sensing technologies capture an individual's behavior in playgrounds?

This chapter introduced a novel sensor data-driven approach for capturing children's behaviors. Furthermore, analyzing the sensor data enabled us to identify the environmental aspects the child interacts with in playgrounds.

The next step is quantifying and measuring the impact of these identified environments on children's behavior. For example, installing various play structures in playgrounds might impact children's social behavior differently. One might stay in one crowded area around a popular play structure and interact with peers, while the other might mingle around different spots and make interactions. How can we measure such micro-behavior in the data and analyze their impact over time and space? This has shaped the second research question as follows:

RQ. 2. (Chapter 3): To what extent does the physical environment around the child impact the child's social behavior in playgrounds during recess?

This study explores the impact of spatial features, such as play structures and physical features in playgrounds, on children's interactions with peers. The goals of this study are (1) to introduce a novel spatio-temporal metric to facilitate this investigation and (2) to apply this metric in a case study to obtain a comprehensive understanding of children's social networks in playgrounds.

Feature 2. Individual Experiences.
Including individual experiences enriches the psychological understanding of children's behavior in playgrounds. While sensor data provides multimodal information about children, examining how these measures are aligned with self-report data is crucial. For instance, if sensor data indicates frequent interactions between a child and their peers, does this also suggest that the child experiences a lowered level of loneliness? Thus, the third research question is formulated as follows:

RQ. 3. (Chapter 4): To what extent does including individual differences in experiencing playgrounds facilitate a more accurate interpretation of data?

This chapter aims to include individual experiences, in the form of a self-report, to the sensor measurements to create a clearer picture of children's behavior in playgrounds. Specifically, we use the loneliness measure via self-reports, peer acceptance via peer nomination report, and sensor data to see how children's connectedness in sensor data relates to their level of loneliness.

Feature 3. Spatio-temporal Dynamics.
Analyzing spatio-temporal dynamics enables us to understand an individual's social behavior in space and over time. Previous chapters focused only on face-to-face contacts in playground datasets to capture social interactions, discarding interactions that might happen in other settings, e.g., parallel play. In the next two chapters, we focus on capturing more complex interaction patterns in group settings using artificial intelligence (AI). Due to the necessity of access to ground truth data (i.e., group membership information of individuals over time) to design, train, and evaluate these models, all studies experimented on the Opentraj dataset [37]. This dataset has been collected from pedestrian movements in constrained environments, e.g., university campuses, which to some extent, is comparable to children's movements in playgrounds. In Chapter 5, we are interested in interactions occurring in parallel play, such as running and walking side by side. We have addressed this gap in the next research question:

RQ. 4. (Chapter 5): To what extent can spatio-temporal data identify parallel movements as one specific form of social interaction?

In order to address this research question, we incorporated an AI model to capture similar movement trajectories. Such an AI model provides valuable insights into children's social behavior during play by identifying parallel movements in the playground.

Yet, human social behavior includes complex spatio-temporal patterns that can not be easily modeled via pre-defined forms of interactions such as face-to-face con-

tacts or parallel movements. For example, children's interactions during hide and seek do not include these forms of interactions. Thus, it is important to include both spatial and temporal elements of human interactions in the design of the AI model to capture children's complex social behavior in playgrounds. We specifically addressed this challenge in our next research question as follows:

RQ. 5. (Chapter 6): To what extent does spatio-temporal data of individuals enable us to model group interactions as one form of social behavior?

Chapter 6 aims to adopt AI models to analyze spatio-temporal features in movement trajectories and identify group interactions. By conducting two parallel studies, we examined the use of spatio-temporal data in the form of dyad interactions as well as the inclusion of context information alongside dyad interactions to model group behavior.

Overall, our analysis framework thoroughly addresses the unique characteristics of playgrounds by combining cutting-edge technological advancements with multidisciplinary collaboration involving psychology, architecture, and computer science experts. Implementing this framework offers a valuable tool for schools, sports clubs, policymakers, and designers, enabling them to identify individual and group-level challenges and barriers in micro-communities.

1.3.1 Organization of Thesis

The organization of the thesis is illustrated in Figure 1.1. In Chapter 2, we introduce our sensor data-driven approach that can be used for collecting spatio-temporal data from children in the playground. Introducing a new metric to measure spatio-temporal proximity is discussed in Chapter 3. Chapter 4 discusses the inclusion of children's experiences in our framework. Chapter 5 presents an AI model to capture similar movements. In Chapter 6, we tackle the problem of identifying group behavior via spatio-temporal data. Finally, several remarks are presented in Chapter 7 to conclude this thesis.