

# An Ontology Design Pattern for Semantic Modelling of Children's Physical Activities in School Playgrounds

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## 1. Introduction

Ontologies are formal, partial specifications of our knowledge, and intended to promote communication between and among humans and machine by clarifying intended semantics. For a given domain, ontologies can be designed at different levels of conceptual granularity depending on the scope and detail of the concepts that are expected to be important in reasoning about the domain. In the field of mobility and movement analysis, most of the research is focused on issues related to data modeling, algorithm development, and creation of tools for visualizing and analyzing movement in specific contexts. However, looking forward, we anticipate the role of ontologies becoming central in analyzing and making predictions from movement data. *Ontology design patterns* (Gangemi and Presutti, 2009) are efficient ways to identify and formalize the core concepts of a domain, and make them easily accessible for reuse because of their relative simplicity, modularity and portability.

In this paper, we share initial work on an ontology design pattern being developed for supporting semantic analysis of physical activity patterns of children playing in school playgrounds during recess. Our ontology serves a larger research project with the objective of designing intervention strategies (e.g., designing better school playgrounds) that can entice children to be more physically active, the health benefits for which are manifold and well-documented. The general motivation for our ontology pattern is to clarify physical activity domain semantics, design consistent experimental protocols, and pool data from multiple experiments to engage in rigorous statistical analysis. We see our ontology being useful at all stages of our project—starting from the initial stage of harnessing and processing raw multi-sensor data streams to the later stages when we desire intuitive summaries and behavioral analysis of the children engaged in physical activity. In the rest of this short paper, we briefly describe our PASE project and then discuss how we are using ontologies for semantic modeling and spatiotemporal analysis of children's playground activities.

## 2. Physical Activity Schoolyard Evaluation (PASE) Project

The PASE research project was conceived to develop an empirically-based intervention to increase children's free-play PA during school recess to help prevent or reduce the obesity rate in rural Appalachia. Our objective is to observe and analyze the socio-physical dynamics of children's free play activities during recess at school, and use the knowledge to improve school playground design as well as design intervention strategies to encourage children to be more physically active.

Changes in a playground setting can increase children’s free-play—therefore, many researchers (including us) seek to identify specific cues for physical activity that can then inform the development of effective and low-cost means of promoting playground activity. Video observation and video tagging software provides the means of coding children’s behavior using direct observation, and is the gold standard for assessing children’s free-play. Since this is an extremely time-intensive methodology, we are testing reliability of accelerometry and GPS for measuring children’s physical activity intensities and durations within different playground zones, across various age, sex, and obesity groups. Unambiguous location determination becomes difficult when children are near playground zone boundaries (Figure 1) due to positioning errors associated with portable GPS units (with error rates of 3-10 meters typically). Additionally, classical statistical methods used by physical activity researchers will yield suspect results if such uncertainty is not modeled first. For these reasons, we are pushing the envelope by exploring spatiotemporal data modeling and ontology based statistical analysis and decision making in the PASE project.

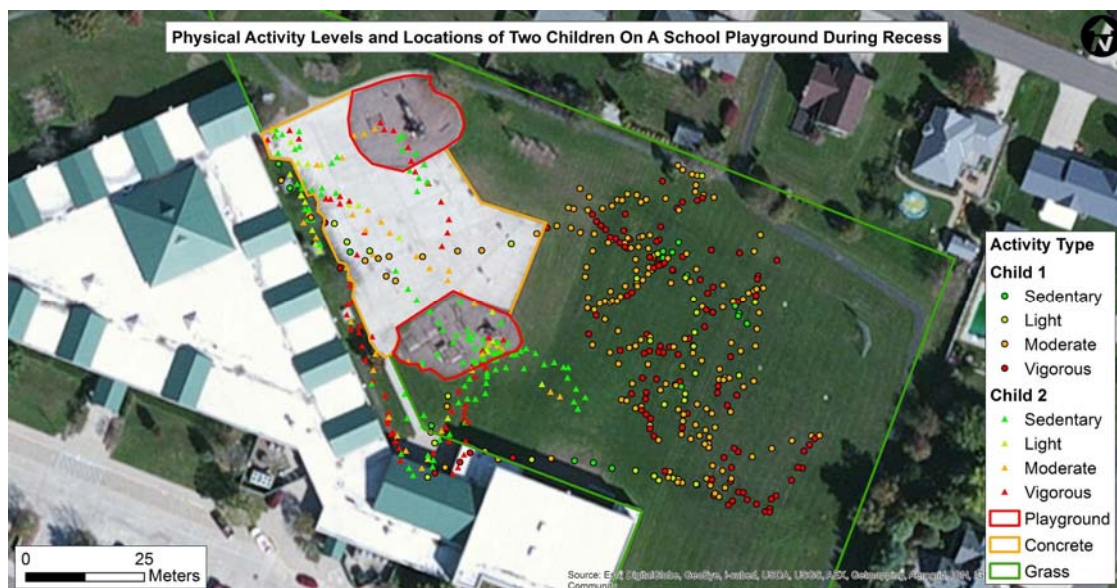


Figure 1. Locations and associated physical activity levels for two children overlaid on a basemap showing playground zones.

### 3. Ontology Pattern Design for PASE

Formalizing our experimental semantics and related background domain knowledge as an ontology pattern helps us communicate and avoid misinterpretations. Ontology design is also helping us identify the best variables for statistical modeling, conceive efficient and elegant data models, and design automated or visually mediated pattern analysis algorithms.

#### 3.1 Motivating the Pattern with Competency Questions

A typical step in ontology pattern design is to motivate the pattern by identifying sample competency questions that can be resolved with the help of the ontology. Sample queries are listed below:

- What is the average PA **intensity** of child X?
- What **types of PA** did child X engage in?
- What proportion of child X's PA is located in **uncertainly buffers of playground zones**?
- What proportion of time did child X engage in **group play**?
- What is the proportion of time **overweight girls** use zone X of the playground?
- What is the proportion of time children are **running** in this school?

These questions helped identify the primary concepts and how they need to be related in the ontology. While these will be better elucidated through diagrams and examples in the presentation, for lack of space, only the key concepts (classes) are outlined below.

### 3.2 Fundamental Classes of the Physical Activity Ontology Pattern

We are designing the ontology pattern to be generic enough to be used for a variety of physical activity research projects, not just for evaluating PA of schoolchildren. The following are the important top level domain classes in our PA ontology pattern, which will gradually be extended with more detailed sub-classes as and when needed.

- **Sensor**: This class helps annotate all our raw data with source sensor details, which are useful in tracking measurement errors and parameterize information retrieval and pattern analysis algorithms. For example, statistical models for converting accelerometer counts to PA levels are dependent on the type of accelerometer; position errors vary with GPS receiver unit types; video derived playground locations have no error. Other types of mobile health sensors could also be used in PA research.
- **Moving Agent**: The age, sex and weight of the moving agent (child) are important properties for our PASE project. We also may include additional properties to capture some socioeconomic background information about children.
- **Physical Activity**: PA can be described quantitatively and qualitatively. Currently, we rely only on a regression model derived cut-off points (specific by to age class and type of accelerometer sensor) for classifying accelerometer raw activity counts into one of the four physical activity levels (*sedentary, light, moderate, and vigorous*). Other studies may use other thresholds and/or classification methods, such as expressing PA in terms of Metabolic Equivalent of Task (MET) units. This class supports capturing all such semantics of PA measurement.
- **Environment**: Since different experiments on physical activity will happen in different environments and at different spatiotemporal scales, we define a generic upper level class called *Environment* and recognize two sub-classes: *Static Environment* and *Dynamic Environment*. For our research, **Playground** is the most important subclass *Static Environment* and defines the maximum spatial extent of any particular experiment. We partition playgrounds into specific zone types (e.g., concrete court, grass field, play structure; if needed, play structure could be further classified into jungle-gym, see-saw, slide, climbing wall). Further, each playground zone is also partitioned into an inner, "certain" region and a peripheral, "uncertain" region (an interior buffer around the zone boundary) to explicitly account for GPS errors). **Weather** is a sub-class of *Dynamic*

*Environment* and its properties include season, numerical temperature, and qualitative temperature (cold, cool, warm, hot). Other sub-classes of *Environment* maybe added later.

- **Semantic Trajectory:** A semantic trajectory is captured by a GPS sensor, but it not only captures spatiotemporal fixes but also relates them to activity types and places. We import an existing trajectory ontology pattern to semantically model GPS sensed trajectories (Hu et al., 2013). We extend the trajectory ontology’s *Attribute* class with additional classes and properties to describe *trajectory motion* (e.g., speed, acceleration, azimuth) and *trajectory path* (locations, displacement, sinuosity) parameters. The modified trajectory ontology also led to a new PA trajectory data model and we are currently researching PA trajectory interpolation and spatiotemporal buffering algorithms.
- **Motion Events:** Trajectories are “traversed by” moving objects (e.g., children in free play), and thus contain information that can be pattern-analyzed to detect occurrences of a few generic *motion events* (start, stop, continuation). These motion events, in turn, become important building blocks for defining (and detecting) occurrence of more complex play behavior patterns. The semantics of *motion events* is proving to be a challenge to formalize as an abstract top-level concept. We are still evaluating multiple event ontologies that could be used to define the generalized semantics of motion events.
- **Movement:** *Semantic trajectories*, *motion events*, and (accelerometer-derived) *physical activity* level semantics can ultimately be combined to define and recognize more complex movement patterns in space-time. The classification of generic and behavioral movements in Dodge et al., (2008) is our starting point for describing and classifying children’s movements in the playground, but we are also working on defining the semantics of more specific movement patterns (e.g., moving, walking, running, pacing, lying, sliding, hanging). Two special movement patterns (*meet* and *movement of cluster*) could suggest social or group play, detection of which is quite important for our analyses. The semantics and formal specifications of movement patterns is again extremely complicated, and instead of abstract specifications, we may have to begin with sensor specific semantic modeling.

## 4. Conclusion

We have found the ontology pattern design process quite beneficial so far in clarifying the conceptual and computational basis of our interdisciplinary project. Our pattern design is still ongoing and there are several details about our experimental set-up, the variables of interest, sensors, statistical modeling that need to be determined. More specific details of this ontology pattern which is being implemented as an OWL ontology will be available by the time of the workshop presentation. Most importantly, we stress that this ontology pattern when finished can be easily adapted and extended for semantic modeling of any type of physical activity.

## References

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