An ontology pattern for semantic analysis of multi-sensor observations of children’s activities in school playgrounds

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INTRODUCTION

Given the complexity of reasoning with spatiotemporal data and the ever-changing scope and nature of sensors, it is not surprising that most research and application is focused on data modeling, algorithm development, and creation of tools for visualizing and analyzing such information. For smart decision making, we also need to foster work on spatiotemporal ontologies that help abstract the higher level semantics of human movement patterns at different levels of conceptual granularity. Both Lagrangian and Eulerian spatiotemporal ontologies are needed to move up the inference chain from initial processing of raw multi-sensor data streams to intuitive summaries and predictions about human activity as they unfold in space-time. In this workshop presentation, the author will present an ontology being developed for supporting semantic analysis of multi-sensor data collected for physical activity research for human health improvement.

PHYSICAL ACTIVITY MODELING OF CHILDREN PLAYING AT SCHOOL

Motivated by the link between physical activity and childhood obesity, the authors are collaborating to collect pilot experimental data about children’s physical activity patterns recess in elementary school playgrounds. Our immediate objective is to understand the socio-physical dynamics of children’s play activities in school playgrounds and offer suggestions to promote physical activity during recess. Our experimental set up is designed to collect spatiotemporal data from multiple sensors (GPS and accelerometer on children’s bodies, and video cameras around the field) that help us assess the differential effect of playground location (fields, courts, play structure types) and social engagement (solitary vs. group play) (and, secondarily, also gender, weight, weather) on physical activity duration and intensity. An ontology based approach is optimal for this project to clearly specify the relationship between higher level concepts and applied experimental measures. The ontology will also help in designing the user interface for our information system, reason about impacts of measurement errors, and integrate and reason with data from multiple sensors from different experimental set ups.

ONTOLOGY PATTERN DESIGN

The physical activity ontology is being designed as a small ontology pattern that will be linked to other ontologies. We have followed the basic principles of the ontology design pattern process which leads to compact and modular ontologies that are easy to reuse and combine with other related ontologies (both developed by others and our team) for the domains of physical activity and mobile health monitoring. Sample semantic queries that we need to answer immediately are as follows:

- What is the average PA intensity of child X?
- What types of physical activities did child X engage in?
- What proportion of time did child X engage in social play?
- How many overweight girls use zone X of the playground?
- How many stable cohorts can be detected during recess?
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 are outlined below.

- **Sensors**: The Semantic Sensor Network (SSN) ontology from W3C is going to be used (only some classes) in our ontology to annotate our data with requisite sensor details because for both automated information retrieval and tracking measurement errors, we need to explicitly maintain links between sensor types and the concepts that they can support reason about (reliably). For example, RFID sensors support only relative proximity but GPS units also provide absolute location. GPS data is much easier to process than video records, but GPS positioning errors are a major concern. Accelerometer data are both faster and more accurate than GPS or video data for determining physical activity levels. Yet, redundant measurements from sensors are also necessary for error control.

- **Physical Activity**: We currently define four physical activity levels: *sedentary, light, moderate, and vigorous*. While it is possible to use trajectories and motion patterns to derive these activity types, we rely only on accelerometer records because we use age-specific thresholds for classifying a child’s accelerometer measured instantaneous intensities into one of the four physical activity levels. Our ontology clarifies such semantics and tracking the sensor used to derive activity levels is crucial for comparing results from different sensors or performing semantic integration of data between studies that may use both GPS and accelerometer records to determine physical activity levels.

- **Movement**: We import an existing semantic trajectory ontology to model GPS sensed trajectories. We introduced additional trajectory parameters to describe trajectory movement (e.g., speed, acceleration, azimuth) and path (locations, displacement, sinuosity) parameters. These parameters will help detect simple, discrete motion events (e.g., start motion, acceleration, deceleration, continuation of motion, stop motion) and more complex movement patterns (e.g., moving, walking, stopping, running, hovering, dancing) as well as design interpolation algorithms for imputing missing fixes. Conventional physical activity research mostly ignores the temporal information of GPS position fixes.

- **Proximity and social play**: The concepts related to trajectories also are necessary for determining patterns of proximity between individuals to detect cohorts of two or more individuals engaged in social play. Without video records, reasoning about trajectories to automatically detect occurrence of social play is not trivial. However, it is a critical event to detect for testing individual vs. group play impacts on physical activity levels.

- **Play zone**: We partition playgrounds into increasingly specific zone types (e.g., concrete court, grass field, play structure; and 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 inaccuracy in locating children.

- **Other Concepts**: Additional concepts that need to be identified include weight and age groups, and weather conditions.

**CONCLUSION**

We intend to create a comprehensive ontology of physical activity and mobility for human health research for semantic analysis of multi-sensor data being collected at several spatial and temporal scales (from few minutes on a playground to several days at city or regional scale). Because of our commitment to modular and abstract thinking, our ontology and data modeling is also quite extensible (with some modifications) to other mobility pattern analysis projects. More details of this ontology pattern which is being implemented as an OWL ontology, and how we are integrating existing work on ontology of sensors, spatiotemporal phenomena, and movement pattern analysis will be shared at the workshop presentation.