AIDA: an Adaptive Immersive Data Analyzer

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Abstract

In this demonstration, we show various querying capabilities of an application called AIDA. AIDA is developed to help the study of attention disorder in kids. In a different study [1], we collected several immresive sensory data streams from kids monitored in an immersive application called *the virtual classroom*. This dataset, termed *immersidata* is used to analyze the behavior of kids in the virtual classroom environment. AIDA's database stores all the geometry of the objects in the virtual classroom environment and their spatio-temporal behavior. In addition, it stores all the immersidata collected from the kids experimenting with the application. AIDA's graphical user interface then supports various spatio-temporal queries on these datasets. Moreover, AIDA replays the immersidata streams as if they are collected in real-time and on which supports various continuous queries. This demonstration is a proof-of-concept prototype of a typical design and development of a domain-specific query and analysis application on the users' interaction data with immersive environments.

1 Introduction

With *Immersive Environments*, a user is immersed into an augmented or virtual reality environment in order to interact with people, objects, places, and databases. Many prototypical applications of these immersive environments already exist (see [3] for a list). In a previous publication [1], we reported on the implementation of an immersive environment, called *the virtual classroom (VC)*, designed to conduct attention testing. In particular, the application focused on the assessment of attention process in children with Attention Deficit Hyperactivity Disorder (ADHD). With VC, we conducted trials with 18 children experiencing a virtual class environment through a Head Mounted Display (HMD). The children were asked to complete a task in the presence of different types of virtual distractions. While they were accomplishing the task, we collected several immersive sensory data streams including their body movements through trackers. This valuable dataset, termed *immersidata*, is a rich source of information by analyzing which we can learn a lot about the kids behavior as well as the application itself. For example, one can issue complex queries on the dataset retrieving high-level behavioral patterns such as *loss of attention* or even differentiate between ADHD-diagnosed and normal kids.

In this demonstration, we present AIDA, a data analyzer for the virtual classroom. We show our schema developed for VC on top of an OR-DBMS. AIDA's database which is built in Oracle 9i stores three different sets of data. The first set includes all the geometry data of the VC's virtual environment such as the shape and location of a blackboard. AIDA uses Oracle Spatial Option to conceptualize this set as spatio-temporal data. The second set is similar to traditional record-based data and includes the personal profile about each kid, her answers to pre and post experiment questionnaires and the mouse clickstreams responses to the VC tasks. Finally, the third set is the streamed data acquired from a kid's interactions with VC. The immersidata mainly includes the position and orientation of a kid's head, legs and hands generated by various trackers on the body parts.

AIDA exploits the schema to support sophisticated and useful queries on the kids' interactions with the application. AIDA's graphical user interface facilitates forming spatial and temporal parameters for various query types on the VC data. Moreover, we have implemented a simulated immersidata generator within

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AIDA. This simulator *replays* the kids' interactions with VC and the spatio-temporal behavior of its objects. Subsequently, AIDA supports online continuous queries on the corresponding data streams. The online query component of AIDA can be incorporated in a real-time query interface for VC. Furthermore, the support for online and *continuous* queries in AIDA provides useful inputs for the future *feedback driven* applications [3].

The remainder of the paper is organized as follows. Section 2 describes the virtual classroom application. Section 3 discusses AIDA's components, namely its database schema, queries and GUI. In Section 4, we describe research issues in immersive data query and analysis. Section 6 draws the conclusion.

2 The Virtual Classroom Application

The *Virtual Classroom* is an HMD virtual environment designed to test attention performance in normal children and those diagnosed with ADHD [1]. The objective of the application is to differentiate these two user groups by analyzing their performances within VC. The VC's virtual environment consists of a typical classroom with all common objects (e.g., desks and chairs). A typical VC task consists of alphabetic characters that are sequentially displayed on the blackboard with the child instructed to press a button when a particular letter pattern (e.g., an X preceded by an A) is seen. At the same time, a series of typical classroom distractions are systematically manipulated within VC. In addition to the attention response measures, trackers placed on the head, hands and legs monitor body movements of the child and stream the data continuously.

Upon collecting such immersidata over a series of trials, psychologists would like to be able to ask a variety of queries about the stored dataset. The queries can be as simple as: "Which distraction was present when a particular child missed a target?", to more complex queries such as "Automatically distinguish ADHD children from normal ones". We conducted a clinical trial using VC with 8 physician-referred ADHD and 10 nondiagnosed children and stored their interaction data in AIDA's database.

3 AIDA's Components

In this section, we first conceptualize the VC's data using an object-relational data model. This conceptual database design is included in the Stream Query Repository (SQR)[1], a repository of data stream schema and queries maintained as a resource for researchers in data streams. Then, we briefly discuss different query categories supported in AIDA. Finally, we describe the look and feel of our demonstration.

[1] http://www-db.stanford.edu/stream/sqr.

3.1 Database Schema

We used the general schema proposed in [3] to design the database schema of AIDA. According to [3], the main components of an immersive environment are subject(s), *virtual space*, *actor objects* and a task objective, *mission*. We briefly define each in turn. **Subject** is a human character who performs a task in the environment. During the task performance, she interacts with virtual objects and/or other subjects in the environment. **Virtual space** is a simulation of real world generated using Virtual Reality (VR) techniques or Projected Videos. The space is defined as geometry of some static *scene objects*. These are static objects like chairs, desks and blackboard in the VC application. **Actor objects** are objects whose appearance or disappearance in the space or their changes in position during the system lifetime are main causes of the system events (e.g., characters displayed on the blackboard in VC). **Mission** is the task which a subject is asked to perform while immersed in the environment. Recognizing AX patterns is the main mission of VC.

Different entity types are required in order to describe different datasets generated by and maintained for an immersive environments such as VC. These datasets are categorized into three groups. The first group of entities conceptualizes various traditional datasets within VC. The conventional relational model would suffice to describe these datasets:

- `Subjects <sid, age, gender, type>` represents the subject(s) monitored within VC.
- `OnlineInput`$_s$[2] `<sid, time, response>` includes subject's answers to the VC mission as mouse clickstreams.
- `OfflineInput <sid, question, response>` specifies subject's answer to off-line questionnaires before or after the VC mission.

The second group describes the spatial and temporal datasets. The object-relational model is used to describe these data types. For implementation purposes, an object-relational database with spatial and temporal extensions can be used. In this demonstration, we have used Oracle 9i with Oracle Spatial Option installed in order to store and query the VC's spatial datasets. Spatial, geometry and temporal aspects of objects are provided accurately by the rendering subsystem. The `position` attribute in the following entities is implemented as a `SDO_GEOMETRY` data type in Oracle spatial cartridge:

- `SceneObjects <soid, name, position>` contains geometry of scene objects that constitute the virtual space (i.e., a classroom in VC).
- `ActorObjects <aoid, name, type>` are dynamic moving objects in the environment (e.g., a flying paper plane).
- `ObjectsTrajectory`$_s$ `<aoid, time, position>` represents *actor object* movements.

[2] We use the subscript s for the entities whose corresponding dataset is a data stream.

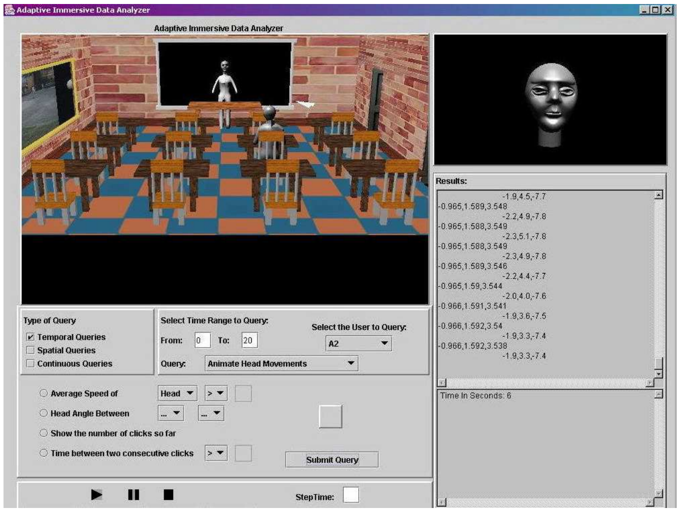

Figure 1: The main interface window of AIDA

The immersidata, conceptualizes data generated as a result of subject(s) interactions VC:

- BodyPositions$_s$ <sid, partId, time, position, rotation> specifies the position of each part of the subject body as well as the rotation of the part with reference to a 3-D coordinate space. This information has been acquired during the mission through the trackers.

3.2 Queries

We have implemented a rich set of queries to extract a subject behavior or search for patterns of interest from the subject's interactions with VC. Although AIDA is a specific data analyzer for the VC application but this interactive system supports various predefined queries which are common across different immersive environments. Below are some examples of the queries:

Subject behavior queries are focused on extracting relationships among her performance during the mission, her body movements and the events occurred in the environment. As an example, *subject attention* is a common behavioral concept that can be identified by analyzing subject's interactions. This concept is useful to evaluate the subject performance after a mission. We define subject attention based on whether she should have been distracted while performing a VC task or not. In our conceptual design for the VC application, appearance of an actor object within a certain distance of subject can potentially result in a distraction. If the subject has moved her head towards the object, a distraction has occurred.

Subject performance queries report the quality of her responses to the corresponding task while she was interacting with the environment components. One simple example is this query: *"Grade the subject based on the number of correct button clicks and missed AX patterns"*.

Spatio-temporal range queries can retrieve components based on their both spatial and temporal dimensions. Different query types are identified in this category based on the definition of spatial or temporal range window. For one class of range queries in the form: *Report all the objects with a distance more than d from the subject in the first 10 seconds of the mission*, the temporal window has a fixed width. A different query is defined when temporal or spatial window size is the result of another query. For example, *"Which actor objects were within a distance d of the subject during the times that she was looking to the left?"*

Spatial/Temporal kNN queries[3] are specified with a temporal range and a kNN predicate on spatial dimensions or vice versa. An example of the implemented kNN queries is *"Identify the 2 closest actor objects to the subject in the recent 20 seconds"*. We use spatial primitive functions provided by spatio-temporal databases for retrieving N nearest objects to a given object.

Spatial aggregate queries deal with abstractions of subject and/or object locations in space. For example, *"What is the average speed of the subject's leg movement during the VC mission?"* or *"For each subject, report the total distance of her head movements"*. **Temporal aggregate queries** are specified by aggregating the temporal dimension of entities. For example, *"What is the subject average response time to AX patterns?"* or *"What is the percentage of the times when subject was not looking at the blackboard during the whole mission period?"*

3.3 Continuous Queries

We have built a simulated data stream generator within AIDA that replays the immersidata streams as if they are collected in real-time during the experimentation with the VC application. AIDA's *stream mode* addresses common stream processing challenges to answer continuous queries issued on the *replayed* immersidata streams.

We have implemented continuous version of the queries described in Section 3.2. With the *stream mode*, each query is assigned a sliding window parameter. An example of a continuous spatial aggregate query using a sliding window is *"Continuously report the average speed of the subject's head movements during the recent 10 seconds."*. The result helps to find the subject's specific disorders in the real environment. Likewise, a continuous behavior query helps to monitor the subject in real-time and direct her attention to the task. An example is *"Show a warning when the subject is looking at the window."*.

3.4 Graphical User Interface

AIDA is implemented in Java, using JDBC protocol for connecting to the back-end OR-DBMS. As it is shown in Figure 1, AIDA's user interface consists of several frames. In the upper left window, the immersive classroom as it is seen by the subject is mod-

[3] k-nearest neighbor search

elled. This 3-D model has been generated based on the spatial data maintained about the immersive environment. This model displays the general plan of the class, location of the subject, scene objects and distractions (e.g., activities occurring outside the window). In the upper right window, a head model representing the subjects head is displayed based on the immersidata generated by her head tracker. The movements of the subjects head during the mission can be visualized by this model. In the bottom window, the user can choose either spatial or temporal types of queries and specify the appropriate parameters. Different input controls have been provided to specify required temporal ranges for temporal queries as time intervals relative to the total duration of each mission.

In the *static mode*, all the queries are issued against the data stored in the database. Since the received data from the immersive environment can be used to represent the animated model and reconstructing the events, typical media browsing controls (e.g., play and pause) have been provided in the user interface. Using this set of controls, user can easily *replay* the mission for each subject in order to verify the validity of the query results. In the *stream mode*, AIDA provides the user with the ability to perform online and continuous queries on the replayed data streams as if they are being generated from the actual VC environment.

4 Research Issues

In this section, we briefly describe our previous studies in managing immersive datasets. In [1], we reported on how the virtual classroom application is used for the study, assessment, and rehabilitation of human cognitive and functional processes. We reported our initial observations revealed after a clinical trial conducted with 18 normal and ADHD-diagnosed kids.

In [3], we provided a framework towards the modelling data of immersive environments after studying several prototypical immersive environments. We showed the effectiveness of our model by using it in formalization of a wide range of complex queries from knowledge discovery to spatio-temporal queries.

In [2], we introduced *AIMS*, An Immersidata Management System. We discussed the challenges involved in managing the multidimensional sensor data streams generated within immersive environments. We studied the challenges of two main modes of operations on immersidata: off-line and online query and analysis. In addition, we proposed complementary approaches for efficient acquisition and storage of immersidata. The core promising idea behind *AIMS* approaches is a *'database friendly'* utilization of linear algebraic transformations on both datasets and queries to efficiently abstract, aggregate, classify and/or approximate multidimensional data streams.

We studied online stream queries over immersidata in [4]. We focused on recognizing a specific behavior by real-time analysis of immersidata as it becomes available, e.g., recognizing American Sign Language (ASL) sign from a user's hand motion. We viewed this problem as *real-time pattern isolation and recognition over immersive sensor data streams.* We first proposed a distance metric, Weighted-Sum Singular Value Decomposition (WSSVD), suitable for similarity measurement of immersive data sequences. Subsequently, we proposed a mutual information based heuristic for segmentation of the immersidata sequences.

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6 Conclusion

We described AIDA, an application to help the study of attention disorder in children. We implemented AIDA's database using an object-relational database and populated it by data pertaining to the virtual classroom application. Within AIDA, we incorporated a rich set of continuous and static spatio-temporal queries whose answers help in assessment and rehabilitation of ADHD-diagnosed kids. Moreover, AIDA employs animation to replay the real-world experiments, illustrates the kid's behavior, and supports online continuous queries. We believe that AIDA's database schema design and efficient querying capabilities are common for general immersive environments. As a proof of concept for our ongoing research on immersive datasets, AIDA showed the effectiveness of our data model by incorporating different classes of general-purpose and application-specific continuous and static spatio-temporal queries.

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