Automatic Updating of Computer Games Data Warehouse for Cognition Identification*

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Keywords: Cognitive Skill Mapping, Computer Games, Automatic Database Integration, Automatic Database Mining.

Abstract: This paper describes the algorithms (called OTEP_DW_auto) for automatically updating the integrated games data warehouse and cognitive profile data sources for purposes of identifying child's cognitive skill level. The techniques described in this paper represent an extension to the data integration engine adopted by an online product called "Thriver" developed by OTEP Inc. (Online Training & Evaluation Portal). OTEP focuses on using the Internet, natural playing environment for online computer games to give parents and care-givers automated opportunity to screen and follow their children's cognitive development. Current data integration efforts of the system when new games (such as speech games) are added or new cognitive skills matrix are added would require manual re-coding of the system which is a costly and time-consuming process. The cognitive skills matrix maps cognitive skills level of games player such as "basic reading level is good" to their games performance in comparison to the norms of other players. The proposed OTEP_DW_auto is capable of building the OTEP data warehouse schema automatically, thus seamlessly extracting, cleaning and propagating data from various data sources. It also provides a dynamic GUI-based interface for answering tens of frequently asked cognition-related questions.

1 INTRODUCTION

With the proliferation of hand-held devices such as computer laptops, tablets, and smart phones, there is increased easy access to online resources and video games. There is a body of research that points to unique learning habits of young people who prefer short visual explanations, to receive information quickly, prefer multi-tasking and non-linear access to information, have a low tolerance for lectures, prefer active rather than passive learning, and are kinaesthetic, experiential, hands-on learners who must be engaged with first-person learning, games, simulations, and role-playing (Junco and Mastrodicasa, 2007); (Oblinger and Oblinger, 2005); (Tapscott, 2009). Although playing computer and video games are largely seen as a distraction to learning, they are recognized as valid cognitive activities since they affect a player's ability to self regulate, make right decisions, and problem-solve ((Dance, 2003), p. 177).

The goal of this research is to use already available technology devices (computers and online video games) accessed by youth to identify children with learning differences that may be affecting their learning abilities (e.g., the acquisition, retention, understanding, organization of information). This research discusses an extension to an earlier system (Whent et al., 2012) for identifying a child's cognitive skill level called "Think-2-Learn" (presently renamed "Thriver"), created by OTEP Inc. (Online Training & Evaluation Portal).

Section 2 presents the related work on computer gaming, cognition and learning, OTEP's Thriver data warehousing and mining approach, and on some existing data warehousing schema integration approaches. Section 3 presents the new additional automatic data warehouse integration approaches being proposed for advancing the OTEP solution, including the automatic data warehouse schema integration algorithm, automatic querying and data cleaning algo-

*This research was supported by the Social Sciences and Humanities Research Council (SSHRC) and FED DEV/OBI and NSERC grants of Canada.

rithms. Section 4 discusses performance analysis of how games data can be effective in identifying cognition while section 5 presents conclusions and future work.

2 RELATED WORK

2.1 Computer Games, Cognition and Learning

Positive effects of playing computer games on cognitive development include improving visual intelligence skills which are useful in science and technology, and generally in such fields requiring manipulation of images on a screen (Subrahmanyam et al., 2000). Although other consequences of playing computer and video games have been studied (Martinovic et al., 2011) computer-based games may enhance hand-eye coordination, visual scanning, auditory discrimination, and spatial skills (DeLisi and Wolford, 2002). It has been stated that repetitive game playing may increase young children's working memory (Thorell et al., 2009), mental rotation accuracy (DeLisi and Wolford, 2002), and spatial rotation, iconic skills, and visual attention (Subrahmanyam et al., 2001). Playing the carefully and purposefully designed computer games may positively affect learning among children of wide range of ages (Subrahmanyam et al., 2000), (Martinovic et al., 2014a), (Martinovic et al., 2014b). This is because playing computer games involves integration of "touch, voice, music, video, still images, graphics, and text" (IBM, 1991), and can stimulate a variety of intelligences (e.g., linguistic, logical, spatial, kinaesthetic, musical), that may particularly influence development of literacy skills and ability to problem-solve.

2.2 Data Warehouse Schema Integration Approaches

A data warehouse is a historical, integrated, subject-oriented database storing data from multiple data sources in the one data warehouse schema (Han et al., 2011). Construction of a data warehouse is done through processes of schema and data integration of different data sources which involve data cleaning (Ezeife and Ohanekwu, 2005), data transformation and loading with periodic refreshing. A popular data warehouse schema approach is the star schema where there is a central fact table having foreign key attributes that include the main subjects of interest, the integration attribute, the historical time attribute and some non-foreign key aggregate measures of interest. Other descriptive tables in the data warehouse design using the star schema are dimension attributes for describing the foreign key attributes in the fact table (Ezeife, 2001). A measure such as score achieved during a game by a child can be calculated from a multidimensional model version of the data warehouse called the data cube (Ezeife, 2001). Existing schema integration approaches (Kern et al., 2011), (Fan and Poulovassilis, 2004), (Rahm and Bernstein, 2001) process some common steps during schema integration. The first step in integrating schemas (e.g., integrating schema1(Cust, C#, CName, FirstName, LastName) and schema2(Customer, CustID, Company, Contact, Phone)) is to identify and characterize these inter-schema relationships between the multiple data source schemas to be integrated. This schema element relationships can be identified automatically through integration approaches such as application domains, match operator, architecture for generic match, schema-level matchers, instance-level approach. Application domains approach integrates an independently developed schema with a given conceptual schema and requires semantic query processing. Once these schema relationships are identified, matching elements can be unified under a coherent, integrated schema or view. Match operator requires a representation for its input schemas and output mapping and needs to explore many approaches to match. For example, the result of calling Match on the two schemas above could be Cust.C# = Customer.CustID, Cust.CName = Customer.Company, and {Cust.FirstName, Cust.LastName} = Customer.Contact. Schema-level matchers only consider schema information, not instance data. The available information includes the usual properties of schema elements, such as name, description, data type, relationship types (part-of, is-a, etc.), constraints, and schema structure. Instance-level data can give important insight into the contents and meaning of schema elements. For example, a data-guide or an approximate schema graph can be generated automatically from XML documents. In (Kern et al., 2011) a framework for building logical schema for federated data warehouse from different data warehouse resources was proposed. The logical schema of the federated data warehouse is generated as a result of integration of components of data warehouses (the fact and dimension tables). The input to the integration process consists of several sets of fact table (F) with dimension tables (Dim) that are related to the fact table F through foreign key constraints. To integrate the data warehouses into one federated data warehouse, the algorithm begins with an empty fact table (F_output), and for each measure aggregate attribute in an input fact table F_input, it looks for a corresponding measure attribute and if it exists, it defines the mapping between these two attributes in the input and output fact table. If it does not exist in the output fact table, then, the new measure attribute is inserted in the output fact table and the mapping between these input and output fact table measure attribute is defined and inserted. Then, for each dimension table in the input data warehouse, D_input, it matches the foreign key attribute of the table with those of the output dimension table if this input dimension table exists in the output data warehouse and defines the mapping between this input dimension table and the output fact table. If the input dimension table does not exist in the output data warehouse, or none of its attributes match in schema F_output, then it adds the dimension table to federation schema F_output. In (Fan and Poulovassilis, 2004), a heterogeneous data transformation and integration system, named AutoMed, that offers the capability to handle data integration across multiple data models and supports a low-level hypergraph-based data model (HDM) was proposed. For any modeling language M, data source wrappers translate data source schemas expressed in M into their AutoMed representation, and for every construct of M there is an adds and a deletes primitive transformation which add to/delete from a schema an instance of that construct.

2.3 OTEP Data Warehouse Integration Approach

Whent et al. (2012) presented the OTEP system which uses online games to screen or assess children's cognitive skills in order to later suggest a learning plan that would be most suitable for their learning success. Thus, the paper described an approach for gathering and integrating the relevant data from (1) video games data, (2) cognitive skills and mapping data and to obtain a data warehouse schema called OTEP GamesDW. The input games data source that was integrated had then, 100 games that a child can play. The games data source containing information about each game, user's record of game plays, user information, game categories etc. were represented in about eight database tables. The second data source integrated into the OTEP GamesDW is the cognitive data source, which describes the cognition levels and their connections to the game instances in the first data source. The system used about 10 main cognitive categories such as Visual Processing, Processing Speed, Auditory Processing, etc., and two to eight sub cognitive categories (e.g., verbal output and written output as sub categories of processing speed). The integrated data warehouse has the following fact table with attributes from games data source and cognitive data source. FactTable(userid, gamid, gameseq, gameDB, gamelevelid, catid, normcogid, cogid, cogsubid, time-m, coglevel, gamescore, duration, tries); This fact table along with accompanying dimension tables can be used to answer queries like What are the cognitive norms (based on cognitive categories attached to the games) and game achievement norms (based on the average game play scores) for children who are 8 years old and who have difficulty reading for a reading game?. Currently, the schema integration is typically performed manually, perhaps supported by a graphical user interface, that is a tedious, time consuming, error-prone, and therefore expensive process. To provide automated support suitable for integrating new changes in the data sources as well as integrating new data sources such as those for connecting learning with both cognitive achievements and games play achievements, we proposed a generic, customizable implementation of the Match operator that is usable across application areas which makes it easier to build application-specific tools that include automatic schema match. Our proposed OTEP automatic integration approach is based on combining the application domains and schema-level matchers.

3 THE AUTOMATIC OTEP_DWH SCHEMA GENERATION APPROACH

3.1 The Automatic OTEP Model and Problem Addressed

In the first phase of OTEP Inc. (Online Training & Evaluation Portal) project (Whent et al., 2012), the data warehouse schema was built manually by the developers. Continuous manual data warehouse integration is tedious and time consuming because the database developer or the administrator spends a lot of time creating the initial schema of the data warehouse. In addition, there is need to keep monitoring any changes in all the corresponding database sources, or to integrate new data sources such as new games sources or learning data source to reflect the change and update the data warehouse schema. Thus, to have a more correct, effective and available data warehouse structure, this paper proposes advancing the initial OTEP system with the ability to do automatic data warehouse integration and refreshing to accommodate new changes in source schemas, or integrate new schemas. It also proposes an automatic querying interface for online analytical processing.

The existing OTEP model (Whent et al., 2012) measures a child's cognitive abilities through his/her performances in repetitive playing of a variety of games in different cognitive categories. The model accomplishes this goal by comparing the child's performance in these games with the performances of dynamically changing normalized performances (termed norms) of other children in similar comparison groups such as age, ethnic background, social background, learning or physical, etc. Thus, OTEP system uses data warehouse integration approach to integrate game playing database, cognitive inventory database, and other data sources such as learning inventory database and online analytical processing (olap) approach with multidimensional views (Ezeife, 2001) as well as data mining approaches for querying. The game playing database can also result from a continuous integration of various gaming sites.

3.2 The Automatic OTEP Data Warehouse(OTEP_DW_auto) Algorithms

The goal of this system is to automatically build, refresh and update the integrated, historical data warehouse of online games play records of children, their cognitive and learning characteristics. These data warehouses are used to screen or assess children's cognitive skills and later suggest a learning plan that would be most suitable for their learning success. This paper describes the algorithms for automatically integrating the relevant data from (1) video games data, (2) cognitive skills and mapping data and to obtain a data warehouse schema called OTEP_GamesDW_auto. In the future, other data sources will be integrated including the learning achievement data and third party data. The current schemas of the games data source and the cognitive data source with the integrated data warehouse are provided in this section. Three automatic algorithms for schema generation, view (querying) generation and data cleaning are presented.

3.2.1 The OTEP_DW_auto Schema Generation Algorithm

The input of the OTEP_DW_auto schema generation algorithm is the Database Name (e.g., Thrivergames, Discovery which are names of the database to be integrated automatically) which contains the connection parameters. After the connection to the database, the algorithm queries the table name sourceStructure

Table 1: A Segment of the sourceStructure Metadata of Two Data Sources.

field Name	field Type	field Size	field Constraint	field Source	field Table Name	field Table Type
user id	Number	20	primary key	Think2 Learn	wp_t2l _user	dimension
user login	Varchar2	20	unique	Think2 Learn	wp_t2l _user	
score	Number	10		Think2 Learn	wp_t2l _game_log	aggregation
duration	Number	10		Think2 Learn	wp_t2l _game_log	aggregation

which contains metadata information (consisting of all the attributes (fields) in the databases and their descriptions) about the two database sources. An example schema for the metadata table, sourceStructure is sourceStructure (fieldname: string, fieldType: string, fieldSize: integer, fieldConstraint: string, fieldSource: string, fieldTableName: string, fieldTableType: string). The description of the steps in the proposed Automatic OTEP_DWH schema generator algorithm are presented next. Step 1: If no data warehouse, called OTEP_DWH already exists in the server, then create an empty data warehouse structure called OTEP_DWH. Otherwise go to Step 9.

Step 2: Sort the table sourcesStructure which is given as input to the algorithm by attribute fieldTableName. Table 1 shows an example, illustrating the structure and contents of table sourcesStructure.

Step 3: Read all the attributes of the table (from fieldName of sourceStructure table) in the database for purposes of mapping to an existing attribute or adding to the existing schema.

Step 4: In this step the algorithm creates all the dimension tables of the data warehouse. The algorithm sequentially reads the value of attribute fieldName from sourcesStructure table as per step 3. It reads the table name of that attribute from fieldTableNameattribute as in step 4.1. It checks whether the table name is marked as dimension table in attribute fieldTableType as per steps 4.2 to 4.5. If the table name already exists in OTEP_DWH schema, then the algorithm adds the new attribute and maps it to the related dimension table. If the table does not exist in OTEP_DWH schema, then the algorithm creates the dimension table with the name of the value of fieldTableNameattribute concatenated with _dim string (to distinguish the dimension tables), the new created dimension table including the attribute as per step 4.4. The algorithm iteratively repeats step 4 for each attribute its tables marked as a dimension table until it builds all the dimension tables.

Step 5:Create the fact table named factTable. The fact table represents the central table of the star schema with major subject, integrated, and historical

attributes. For each primary attribute in dimension tables, the algorithm adds the attribute to the fact table as a reference (foreign key) attribute which refers to the dimension table.
Step 6:add the subject attributes which have a value subject in attribute fieldTableType to fact table factTable.
Step 7:Add the integration attribute to the fact table factTable. The integration attribute is used to distinguish the source of the database from which the original record was fetched.
Step 8: Add the historical attribute to the fact table factTable. The proposed algorithm adds the attribute name dateTime which stores the date and time of creation of the record in the fact table, factTable.
Step 9: Extract all table names and attributes from the source structure table that have fieldTableType value as dimension.
Step 10: For each dimension table, match the table name with given remote database tables to be integrated in the existing data warehouse DWH. We define the match operator with the keyword

```
{%users%, %games%,%collections%,%level%},
 and each keyword has subk-keywords
 for example user keyword has subkeywords
 {%info%,%profile%}.
```

Step 11: For each matched table, extract the data of all the attributes having primary key, and the data into the fact and corresponding dimension tables.

3.2.2 The OTEP_DW_auto View Generation Algorithm

In this phase of the OTEP project, a dynamic graphical user interface (GUI) which allows the end user to query and browse the contents of the data warehouse in different views was built. The interface is user friendly and has the flexibility to compose any kind of query on the data warehouse presenting the result as a view. The following are some queries that can be answered as views by the data warehouse. For this reason, we propose an algorithm to automatically generate the required view by the end user. Algorithm 1 shows the automatic view generator algorithm. Q1) list all students with their ages, source database, and number of played games for all the periods.
Q2) for a given student ID, list all the played games by the student including the completed levels, achieved score, number of tries, and duration.
Q3) for a given student ID, list all played games by student including respective main-category, respective sub-category, score, and derived performance.
Q4) view the matrix performance for a given student in each individual model.
Q5) view the required performance, achieved performance in a specific cognitive skill with a specific/all cognitive main category in a specific model for a given student.
Q6) For a given student ID, list all the played games by the student including score, compared to highest score, lowest score, and norm among all students who played the same games.

Algorithm 1. *(The Automatic OTEP View Generation Algorithm.)*

Algorithm OTEP_DWHview ()
Input: list of all parameter attributes fields (columns need to be shown in query result), condition criteria
Output: view containing the execution result of the query
BEGIN
1. Find the table name in OTEP_DWH data warehouse for each attribute in fields input
2. Create data query language (DQL) as a select statement
3. Concatenate the input condition to the query statement
4. Submit the query to the OTEP_DWH data warehouse and store the result
5. Return the result to the end user
END

3.2.3 The OTEP_DW_auto Data Cleaning Algorithm

Our extraction system faced a lot of challenges during extraction of data contents from each individual video game database source in order to load them into OTEP_DWH. This is because of the different formats and representation of the games data. In addition, it is due to the existence of different database schemas and structures. Thus, we implemented a cleaner algorithm shown as 2 for cleaning and extracting the data of interest and loading it in the right position in data warehouse. The OTEP system also keeps track of all the new modifications such as add, delete, modify table or attribute in database source.

Algorithm 2. *(The Automatic OTEP Data Cleaning Algorithm.)*

Algorithm OTEP_DWHcleaner ()
Input: data records of all database sources
Output: clean data loaded in data warehouse
BEGIN
1. Remove the white spaces of those data records have value of attribute gameStatus equals to completed
2. Remove all special characters and symbols such as {,}, /,[,],<,>,,;
3. For each attribute name located in OTEP_DWH, extract the next token which represents the value of attribute in

the right position in data warehouse
4. For the user_login attribute extract the userID, gender and age of the student because the value of the attribute is given in the format such as 111111_M_14 this means that the studentID=111111 is male (M) and 14 years old age.
END

4 PERFORMANCE STUDY AND USE OF OTEP SYSTEM

The goal of this paper is to propose computer science automatic data integration methods (algorithms) that are used to extend the OTEP system for identifying cognition through repetitive video game playing. Thus, a performance comparison is one which shows that the extensions provided by the new system are correct and more effective in integrating more data sources automatically and handling more complex queries. We shall provide in the next subsections discussions of the extensions provided by the system and details of how to use the OTEP system to correctly identify cognition.

4.1 Correctness of Extensions Provided by New OTEP System

An example automatic integration performed with our extended OTEP system has the ability to integrate more than one cognitive skills matrix model for map the video games performances of a player to cognitive skills levels. In the earlier OTEP system (Whent et al., 2012), only one cognitive matrix model, the Crouse model (Crouse, 2010) was used while the current system proposed in this paper allows integration of more than one model now including also using the Reed cognitive matrix model (Martinovic et al., 2014a). Each of the cognitive models provides both the cognitive classification model (called the cognitive matrix) and the cognitive correlation matrix (called skills matrix). The cognitive matrix model provides a method for classifying simple responsible video games into one of the main cognitive categories and subcategories. The cognitive skills matrix specifies the correlation between areas of cognitive processing and student achievement. For example, with the Crouse model, there are 6 main cognitive categories (such as auditory, visual, sequential rational, concept, speed and executive) and 2 to 8 sub categories such as (short-term memory for visual details, talking speed, etc.). The games in our repository are classified into a main cognitive category and subcategories so that our integrated data warehouse system can be used to gather for each player, the historical game play data such as scores achieved in each game, number of trials for each game level and the time needed to complete each game level. Our system computes the game play norm (average as norm and/or any other measures such as variance, standard deviation) of a comparison group (e.g., all 8 year old, all male players, etc.) so that the performance of the player is compared with this norm and their cognitive level could be identified with the cognitive correlation matrix model (called skills matrix) using a model such as Crouse's or Reed's. The cognitive skills matrix specifies the correlation between areas of cognitive processing and student achievement. For example, with the Crouse model used in (Whent et al., 2012), it is indicated that for cognitive skill of basic reading, in the 6 main cognitive categories of auditory, visual, sequential, concept, speed and executive, a player's basic reading skills is taken to be good if their computed game play record in auditory games is high (as determined using the bell shape and the norms and the standard deviations), visual is moderate, sequential is high and speed is high. The newly integrated Reed's model consists of 9 main cognitive categories and 43 cognitive subcategories.

Another example is that the existing system had been extended with this approach to move from 100 video to about 200 video games in its repository. Other usability features added include automatic querying capabilities with automatic views for a wide range of cognition-related queries.

4.2 How to Use the OTEP System

In our research we work with simple, single-player games that potentially target and measure the key cognitive skills in children and adolescents. In addition to carefully analyzing each game, we also look into the player's performance (e.g., time spent on task, repetition of trials, engagement, and use of hints), note the background information (e.g., grade level, age and gender), and acquire input from their parents and teachers. The list of cognitive skills is presented in a cognitive matrix at the Online Training & Evaluation Portal (OTEP Inc., Whent et al., 2012); it has 9 main cognitive categories (visual perception, visual attention, visual motor, auditory processing, executive function, memory, acquired cognition, social cognition, and emotional cognition) and 43 sub-categories (e.g., visual tracking, selective attention, problem solving, and semantic memory). Our interdisciplinary team uses two web sites; the portal for parents, Thriver.ca, and a site for gamers, ThriverGames.ca, which currently has 167 games.

The games are grouped according to the cognitive skills they employ, based on the cognitive matrix. This classification helps us to determine in which categories we are still missing games, and can also be used when suggesting to children which games to play next. We also invite a child's parents or caregiver to complete a survey about his/her learning style, behaviour, and his/her cognitive strengths and weaknesses. The survey and gaming information are recorded in a database suitable for searching and retrieving data, and producing reports. An enhancement of the software system (the web sites and a database) will use these data to create a personalized plan for the child with recommendations of which games to play next and other strategies that the whole family can use to support their child's cognitive development. These recommendations are based on our extensive literature reviews that are ongoing and will continue throughout this project. This system could be used under a variety of conditions (e.g., in school or at home), could be designed to provide feedback to the child, parent, or professional (e.g., teacher, psychologist), and could work under different models (e.g., behaviourist or cognitive model), based on the parameters selected by the user.

Our target population are 7-12 year olds and their parents/caregivers. There are three ways in which one could participate in our study: (a) as an online games player (contributing to a pool of normative gaming data, based on the playerage, grade level, and gender); (b) as a parent, who completes an online survey and enrolls the child to play games online (where the survey and gaming data are triangulated and a child's cognitive profile is created); (c) as a face-to-face participant in our controlled lab environment (where parents complete the survey and children complete cognitive and academic achievement tests, and are observed during selected game play to record engagement in gaming). Presently we are still collecting data in a controlled environment in which the child does NEPSY II (Pearson) test and plays 15 games that target the comparable cognitive skills as NEPSY II.

So far we have extended OTEP's repository of simple online computer games to 167 games and validated these games to determine (according to the cognitive matrix), the primary and secondary cognitive skills engaged in the players during each game (Martinovic et al., 2014a). We worked in parallel on: a) establishing a literature review in the area of playing simple computer games (i.e., single-player games that are relatively short and are high in activation of specific cognitive processing domains) and their relation to cognitive effects/gains among children, while putting specific emphasis on a design, reliability and validity of instruments and methods used; and b) investigating the feasibility of various methods for evaluating the relationship between games and children's cognitive skills. Based on our present data collection in the lab environment, we intend to establish correlation between: on one side–the child's cognitive skills and learning style, and on the other side–the child's games play data.

5 CONCLUSIONS

In this paper, we presented the extension made to our current work on the online product called "Thriver" developed by OTEP Inc. (Online Training & Evaluation Portal). OTEP video games source databases continues to grow and has grown from 100 to about 200 games whose records need to be integrated into the data warehouses for correct querying. Thus, the need to build an automatic schema and data integrator, view generator and data cleaner for continuous integration of new games and other data sources into the system. The OTEP system is intended to record players' scores to continuously assess and monitor their cognitive strengths and weaknesses with regards to the main cognitive categories. The Web based tool for identifying cognitive skill level is developed as an integration or data warehouse of a number of relevant data sources such as the cognitive skills categories data (which also changes as provided by the psychologists), games data (changing as more games are placed in the repository), player inventory data and so on. The integrated data are continuously mined, analyzed and queried for proper and quick assessment or recommendations.

We continue to work on extending the system: (a) increasing number of games; (b) increasing a reliability of categorization of the games by achieving an agreement between 2-3 scorers; (c) new cognitive matrix categorizations (for example, Crouse's or any other.) (d) developing a formula that will incorporate the features of the game (including differentiating the impact of different cognitive sub categories), the number of trials, the scores achieved and the time spent playing. Future work also include tracking children's cognitive development, proposing remediation in terms of games that may strengthen some cognitive abilities, and increasing validity and reliability of our approach.

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