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Executive Summary

Driven by an initiative of the Adult & Paediatric Diabetes Psychology Service of New Zealand, research has been performed to develop new mechanisms, in the form of computer games, to educate children and teenagers about living with diabetes. Aimed at achieving maximum education effectiveness, the ultimate goal of our research is to develop innovative machine learning algorithms that can be used in games to improve their ability to learn about the changing needs of children and to incorporate this intelligence into the game interface. We also plan to collect and report on the information collected from testing our computer games within a small group of children who have been diagnosed with type 1 diabetics.

Our research plan has been structured into three major stages, starting from modifying some open-source games towards constructing brand new 3D games that are powered by intelligent machine learning technologies for highly effective education. Specifically, at stage one, a joint collaboration has been established between healthcare professionals at the Starship hospital and Unitec staffs from both the Department of Computing and the Department of Performing and Screen Arts. The main objective of this collaboration is to develop a working game prototype that can deliver essential health knowledge to children and meet reasonable usability requirements.

In line with our research plan, fast development of a game prototype becomes the first technical challenge faced by the research team. To tackle this challenge, a decision is made to embed education features, including a variety of visual effects that provide knowledge-rich feedbacks to game players, into an existing 2D game. After evaluating and comparing a number of open-source games, a Java-based Mario Bros game has finally been identified as an ideal base for the game prototype. The Mario Bros game has long been considered as an engaging game for children and can be easily migrated to different computing platforms including mobile systems.

For the purpose of enriching the Mario Bros game with essential diabetes knowledge, we have proposed three important strategies, namely structure enhancement, feedback enhancement, and challenge enhancement, to guide our design of education games. The three strategies are derived naturally from Malone's conditions that help to induce the flow state, which is marked by children's intensive involvement in a series of game-playing activities. Extensive use of the three strategies is clearly evidenced in the design of our first game prototype, which is aimed at educating children with the right skill to manage their diabetes through regular exercise, consuming healthy food, and daily insulin intake.

Implementation of the modified Mario Bros game has been completed successfully. Our game is able to show the blood sugar level of the main character which is called Mario in the game. The dynamic change of Mario's blood sugar level is directly related to Mario's physical activities, such as walking and jumping. When the blood sugar level falls outside a safe zone, the blood sugar indicator will change its color to warn children. Meanwhile a window will pop up and children will be asked to either eat some food or inject a certain amount of

insulin in order to solve the problem. Our game also features a stage-based design. At early stage of the game, a small set of recommended food or insulin injection will be provided when Mario has abnormal blood sugar level. At later stages of the game, the challenge increases and children need to choose among a large variety of food and need to decide the right amount of insulin injection.

Our diabetes education game was successfully presented at Unitec's Kaleidoscope event in July 2011, at URC research forum in October 2011, and at the OZHI conference in December 2011. It has also attracted wide public interests and has been reported in the Advance magazine and the Aucklander. Inspired by the success of the first game prototype, great efforts have been made to design and develop a 3D game packed with more interactive, entertaining and educational features. The 3D game was completely designed and developed by the research team. The implementation of the game will be finalized soon.

In the future, we plan to evaluate our game prototypes with a small group of children at the starship hospital. Hopefully, the evaluation results will shed some new lights on the effectiveness of computer games as mainstream tools for child education. The lessons learned from the game prototypes will also pave the way towards developing powerful machine learning technologies and smart learning environments that promote adaptive and prolonged learning experience.

Background

Diabetes is a lifelong condition which occurs when the pancreas fails to produce adequate insulin required to maintain appropriate blood sugar levels. In recent years, diabetes has become an increasing threat to public health. The Ministry of Health reported that the prevalence of diabetes in children in New Zealand was 0.2% which means that approximately 1700 children had been diagnosed with diabetes by a doctor (most probably type 1).

Traditional method for diabetic education relies heavily on written materials. Although vast amounts of written materials are available for diabetes education, there is only a limited amount of resources available that are targeted at educating children about the condition. Moreover, clinical psychologists often found that written materials, which are passive by nature, are not easily understood by children. Sometimes it appears rather difficult for children, especially those who have recently been diagnosed with diabetes, to cope with their health problems based on the knowledge they learned from these passive materials.

Driven by the initiative of the Adult & Paediatric Diabetes Psychology Service of New Zealand, research has been performed to design and develop proactive mechanisms for diabetes education. As widely known by researchers and clinical psychologists, children who are learning about their diabetic condition will need to learn to cope in a variety of different situations. In view of this, we decided to focus our research on exploiting interactive features of computer games to deliver education knowledge through immersive and situational learning.

Aims and Objectives

Under the umbrella of developing computer games to educate children about living with diabetes and to collect and report on the information obtained from them, several objectives have been identified as explained below:

- To provide a mechanism to collect information from children about their blood sugar levels and insulin usage.
- To provide a central repository for reporting and analysis of the data collected.
- To provide an alternative to paper, in the form of a game, as a delivery mechanism for information about diabetes to children and teenagers.
- To evaluate the usability of the game prototypes for diabetes education in clinical settings.
- To develop innovative machine intelligence technologies for adaptive learning in computer games.

- To gain practical experience of applying machine intelligence to computer games in an education environment.

Methodology

In order to achieve the ultimate goal of creating a smart education environment through wise use of computer games and machine learning technologies, the project has been approached according to a series of major stages as summarized below. Due to the broad scope and technical advancement of the project, stages 3-5 are pending for future research.

Stage one:

In collaboration with industry partners and colleagues in both the Department of Computing and the Department of Performing and Screen Arts, design a series of education games for diabetic children and teenagers. The game design will promote immersive learning under the guidance suitable game design strategies and will also contribute to a prolonged learning experience.

Stage two:

With the help from a research assistant, implement game prototypes according to our design. The implemented games will deliver essential health knowledge to children and meet reasonable usability requirements (the games must be fun to play and the content must be easily understandable to children).

Stage three:

In collaboration with Starship Children's Hospital, systematically evaluate the usability of the developed games in clinical settings. Perform a usability test to ensure that our games can attract reasonable interest from children. Conduct opinion polls to understand children's subjective satisfaction of the games. Run a knowledge test to measure the amount of knowledge learned from playing the games.

Stage four:

Identify several areas of the games where adaptive interactions with people are essential for effective learning. Formalize these areas in the form of mathematical problems that can be solved rigorously through machine learning technologies. Investigate and develop several machine learning algorithms that can effectively address these problems. Research assistants will implement these algorithms in the game prototypes.

Stage five:

In collaboration with the Starship Children's Hospital, conduct preliminary evaluation of machine learning technologies in clinical settings. Run a knowledge test to measure the amount of knowledge learned from playing the game when machine learning is applied. Interview children to find out whether they feel the game is fun to play and whether they can learn more useful knowledge when the game is powered with learning intelligence. Research assistants will participate in usability testing, user interviews, and data collection.

Outcomes/findings

Significant progress has been made in regard to the design and development of the diabetes education game. Main research outputs produced from the project have been summarized as follows.

- A new approach for designing education games has been proposed and applied successfully to develop two diabetes education games. Our design approach exploits the "flow" concept originally used in positive psychology and is comprised of three main design strategies, namely structure enhancement, feedback enhancement, and challenge enhancement.
- A 2D game prototype based on the open-source Mario Brothers game has been developed. Concepts and theories from multiple disciplines, including positive psychology and management science, have been explored for designing and developing this game. The game was demonstrated during the Kaleidoscope 2011 event and has been reported in Advance magazine and The Aucklander.
- Encouraged by the successful development of the 2D game, significant efforts have been made to create a 3D version of the game that provides more interactive and

entertainment features. A prototype of the 3D game is now ready for evaluation. It is worthwhile to note that no existing games have been utilized and the 3D game is completely designed and developed by the research team.

- An abstract that summarizes the research progress related to the design and development of the 2D game has been presented in the Research Forum organized by the Unitec Research Office.
- A paper that reports the research achievements associated with the 2D game has been accepted for publication in an ACM conference (OZCHI 2011, Canberra, Australia). The presentation of the research work in the conference has triggered substantial interests from the audience.
- A new paper that introduces the design and development of the 3D game has been prepared and will be submitted to Persuasive 2012 for review. We are also planning to submit a longer version of the paper to one special issue of the Cognitive Technology journal in 2012.
- A team of 4 students working on the diabetes game project has been short-listed as top 25 teams in New Zealand for the international IMAGINE CUP competition.

A short description of our 2D game prototype is provided below:

The 2D game prototype was developed by modifying a base game called the Infinite Mario Bros which is an open-source variation of the famous Mario Brothers game. We have proposed and applied three design strategies, namely structure enhancement, feedback enhancement, and challenge enhancement, to build our game prototype. Driven by the three design strategies, the main character of the game, named Mario, has type I diabetes. The health related choices faced by Mario become those choices to be solved by the game player. The ultimate goal of the game is to save a princess who is locked in a castle. To achieve this goal, Mario needs to manage his diabetes and stay well while fighting against a variety of evil guards during multiple stages of the game. In order to support immersive and situational learning, diabetes management knowledge has been embedded into the game prototype through various forms. For example, Mario's healthy condition, especially his blood sugar level, is designed as a main challenge at every stage of the game. If Mario's blood sugar level goes outside a healthy region, children's effort to rescue the princess will fail. The importance of the blood sugar level is emphasized through a blood sugar indicator located at the top left corner of the game screen. Meanwhile, aimed at helping children learn the right skills to cope with their diabetes condition, choices regarding food consumption or insulin injection will pop up occasionally when Mario's blood sugar level deviates prominently from the appropriate level. Children need to make right choices through eating healthy food or injecting suitable amount of insulin in order to continue playing the game. The challenge of maintaining appropriate blood sugar level will also increase as children progress through different stages of the game.

Conclusions

Novel game prototypes, including a modified Mario Bros game and a feature-rich 3D game, were developed for teaching children how to manage their diabetes. The results, from the pilot study, demonstrate that participants were positive about the concept of computer aided learning, enjoyed playing our games and believed that games would have added educational value. Further effort will be made to address the feedback received from the pilot study. Meanwhile, to fully understand the effectiveness of computer games for child education, the game prototypes will be evaluated in clinical settings involving children recently diagnosed with diabetes and aged between 7-12 for long-term behavioral changes and increased knowledge of diabetes.

Implications

- Our research project is aligned with the Unitec Research Strategy 2010-2015. It focuses on applied research, and has direct impact and adds value to our stakeholders, including the Adult & Paediatric Diabetes Psychology Service as well as diabetic children and their families.
- The development of computer games and machine intelligence technologies will assist clinical professionals and caregivers to entertain diabetic children and help them effectively control their blood glucose level.

- There is considerable potential for collaboration with industry partners to develop commercial games for health education and for other education purposes.
- Our collaboration with the Starship Children's Hospital will also encourage the use of computer games as mainstream tools for child education in New Zealand. This will significantly contribute to the healthy growth of the local gaming industry.
- This research will advance our understanding of machine intelligence technologies. Specifically, new machine intelligence algorithms dedicated to education and gaming applications will be developed.
- Through this project, our department will further build up its research strength in areas such as computer games and artificial intelligence. Our research will also help to open new funding opportunities from various external channels, including the Health Research Council of New Zealand and Ministry of Science and Innovation.

Publications and dissemination

- G. Chen, N. Baghaei, A. Sarrafzadeh, C. Manford, S. Marshall, and G. Court, "Designing Games to Educate Diabetic Children," in Proceedings of OZCHI 2011, Canberra, Australia.
- G. Chen, "Building a computer game for diabetic education, small thing can make large difference," Unitec Research Forum 2011, Unitec Institute of Technology.
- Game demonstration at the Kaleidoscope Event 2011.
- N. Baghaei, G. Chen, G. Court, and A. Sarrafzadeh, "Design computer games for diabetic education – a clinical evaluation", to be submitted to the Special Issue of Cognitive Technology Journal on Designing Educational Games, 2012 (in preparation).