# AN ARCHITECTURE AND A PROTOTYPE FOR VIRTUAL EXERCISE ENVIRONMENT

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## INTRODUCTION

Physical exercise is encouraged to maintain the functional integrity of the cardiovascular system, muscles, bones, and ligaments. Regularly performed exercise program has been proven by previous research to lower the risks of developing certain types of cancers, cardiovascular diseases as well as other serious illnesses [1][2], and has been reported to be associated with many psychological benefits including lowering depression, anxiety, and stress [3][4]. Individuals who exercise more are usually healthier and tend to enjoy a better quality of life than those who are sedentary. This is especially true for people with lower body disabilities because their sedentary lifestyle brings physical, attitudinal and societal barriers to beginning and continuing a program of regular exercise. Humpel and colleagues conclude that [5] the leading determinants of participation in physical activity include: (1) accessibility of facilities, (2) opportunities for physical activity, (3) safety, (4) weather, and (5) aesthetics. While the review focused on the general population, it is widely accepted that these factors are more important in determining the participation in physical activity by people with disabilities. People with disabilities have lower accessibility to facilities and fewer opportunities for physical activity. Moreover, extreme weather conditions such as excessive heat in summer or excessive cold and dangerous surfaces in winter make it extremely hazardous for them to adhere to a regular outdoor exercise program. Indoor exercise using fitness machines is often plagued by boredom and the resultant poor efforts.

The increasing performance and decreasing cost of computers and trackers make it possible to utilize virtual reality (VR) techniques on the fitness machines in gyms and homes. With proper use of advanced VR technologies and modern hardware, it is possible to design and develop virtual exercise environments providing equally, if not more, engaging, entertaining, and motivating indoor exercise opportunities. The utilization of VR technologies in motor rehabilitation has shown great improvements in learning rate, adherence and some movement parameters of participants [6][7][8]. Schultheis and Rizzo summarized that the advantages of virtual reality in assessment and rehabilitation applications include more naturalistic or “real-life” environments, control of stimulus presentation and response measurement, safe assessment of hazardous situations, increased generalization of learning, increased standardization of rehabilitation protocols and increased user participation[9].

There has been very limited research about the effect of virtual exercise environment (VEE) on the health conditions of people. Most of them use video playback to allow the users to interact with the virtual environment, and show increasing adherence and attendance in the tested samples [10][11]. Commercial VEEs, like NetAthlon and game consoles such as Nintendo Wii, Sony PlayStation and X-Box use video games to motivate their users and show great promise. Video games are reported to provide “fun” and to help keep higher adherence and attendance of players [12]. These commercial VEEs are not suitable for research and development because their architectures are not open, but their success implied that a similar but open architecture for R&D is desirable. Herein, we report the development of a Remote Exercise and Game Architecture Language (REGAL) to create high level immersive VEEs which allow people to exercise just like what we do in the real world. This architecture provides full accessibility for people with lower body disabilities and makes their exercise more enjoyable and less repetitive.

## METHODOLOGY AND EXPERIMENT

The architecture is geared towards open standards for immersive VEE by using open-source or free software and common-off-the-shelf hardware, and is capable of supporting multiple fitness machines, various sports and immersive 3D display. Other researchers and developers can use this architecture to create their own VEEs to their particular research purpose without worrying about the compatibility of hardware or the communication between different components. With carefully selected hardware and tracking only the upper body, this architecture is adaptable to people with lower body disabilities, while still being suitable for able-bodied people.

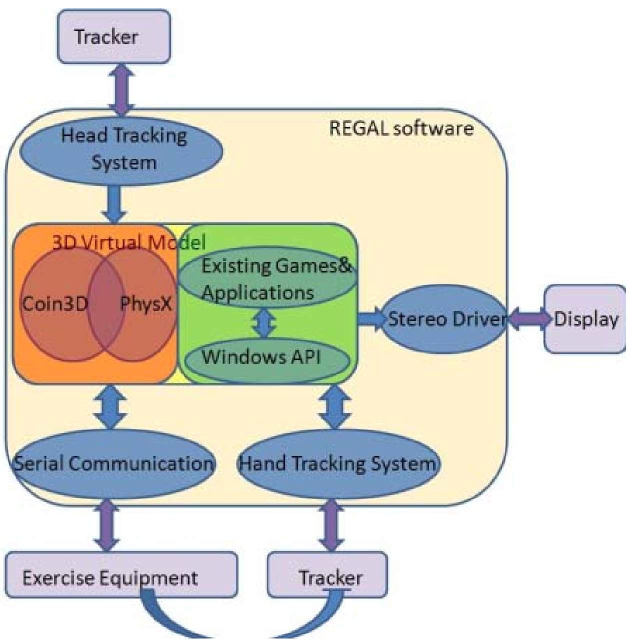


Figure 1: REGAL architecture

The REGAL architecture is shown in Figure 1. This architecture uses tracking systems to get input from the user's body movement. For people with lower body disabilities, the main body movement comes from the users' hands/arms and head. Two independent tracking systems are included to track these two movements respectively. The positions of user's eyes can be tracked by the head tracking system in real-time, so that the corresponding rendered image can be shown on the stereo-enabled 3D display, which makes the users see those virtual objects in the virtual environment just like what people do in the real world. Similarly, the movement of the user's upper limbs can be tracked by the hand tracking system. The tracking systems are responsive to the users' input and also easy to control. The architecture also supports exercise equipments that have serial communication like those supported by NetAthlon. To support an arbitrary equipment, the hand tracking system is mounted to it and the tracking result is used as the input from it to the virtual environment in order to make the architecture independent of any equipment. In this way, any exercise equipment is compatible with this architecture.

Two ways are provided to create the 3D virtual model. One option is to develop a customized VEE by using the provided API on top of the combination of Coin3D and PhysX. Coin3D is an open-source implementation of Open Inventor, which is an ideal toolkit to develop scientific and engineering visualization applications. PhysX is a physics engine to simulate the physics behavior of objects in the real world. The API also includes support of advanced graphics functions like shaders, which allows the designers to customize their own virtual environment. A customized throwing prototype was designed based on this option and was demonstrated at 2009 RESNA (Rehabilitation Engineering and Assistive Technology Society of North America) conference. We collected survey feedbacks from 26 of our users which implied promising potential of the architecture [13].

Figure 2: Demo of rowing prototype

The more powerful option of creating the 3D virtual model in this architecture is to reuse the existing PC games which makes use of the motivation of video games and shortens the development time dramatically. Different groups of people have different choices of video game according to their ages, genders and background, and any individual may choose different games at different time. Flexible support to existing games allows users to have a variety of selections. Moreover, this option also transfers the traditional control of mouse-and-keyboard to control of user's body movement. The transfer from fine motor control to gross motor control changes the traditional sedentary way of playing games, which is considered harmful to health, to a more active way. This transferring can not only benefit those people with lower body disabilities, but also other game lovers.

We designed a rowing prototype to show the support to two popular existing games (FarCry and FarCry2) and the support to two different rowing equipments (the rowing machine from WaterRower and a prototype of universal fitness device). The WaterRower rowing machine was supported via serial communication and the universal fitness device was supported via hand tracking. The user can switch between these two machines or between different rowing handles on the universal fitness device without making any change to the software. This rowing prototype was demonstrated at the 2nd State of the Science Conference of Rectech 2010. The head tracking system was the electromagnetic PCIbird tracking system from Ascension Technologies Corp. and the hand tracking system was built based on the Nintendo Wii remote controller and the managed library for Windows. The rendered images was shown on a 67'' HDTV in 60Hz to reduce the "motion sickness"[14].This demo also shows our concept of transferring fine motor control to gross motor control in playing games which provides the game players more opportunities of exercise while keeping the same game context. 22 volunteers tried the virtual rowing prototype at the 2$^{nd}$ State of the Science Conference of Rectech 2010. The volunteers with lower body disabilities showed roughly consistent satisfaction with able-bodied volunteers. Most volunteers are very happy with the 3D stereo-enabled display and feel very little or no discomfort in the virtual environment. Some users couldn't control their virtual movement very well and reported low responsiveness and naturalness during the trials. This might because they didn't get used to the control in our 15-minute practice session. It's common that people need a certain time to get used to the control of a game.

## FUTURE WORK

Research has revealed that individuals are more likely to engage in a program of regular exercise if it is fun (i.e. the enjoyment outweighs the discomfort) and if they have a "partner" to exercise with [15]. For persons with lower body disabilities, there are far fewer opportunities to exercise with a partner, and exercise may be more likely to be perceived as a chore than as a looked-forward-to part of the everyday activities [16][17]. We plan to implement the virtual environment for multiple users so that users can communicate and even compete with either virtual partners or real partners over the internet. Performance data such as speed, heart rate are usually very important to analyze the participation and adherence of the users. Collection and analysis of performance data will be one important component of the next version of the architecture. A gesture library is also desirable for supporting various exercises such as skiing, walking and cycling. This library will provide individual components to recognize the typical gestures for different exercises.

## CONCLUSIONS

This paper gives a brief description of our current research on an architecture of VEE in which people with lower body disabilities can exercise just like what we do in the real world. The architecture provides the capability to create various enjoyable and engaging VEE by using advanced virtual reality technologies and supporting various exercise equipments and various exercise. The architecture also provides an efficient way to convert fine motor control to gross motor control in playing traditional PC games. The proof-of-concept experiment was conducted to get the users' feedback and to evaluate the quality of the architecture.

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