# Tele-Rehabilitation Games on the Cloud: A Survey and a Vision

**Amal Khalifa[1,2]**

[1]Computer Science Department, College of Computer& Information Sciences, Princess Nora bint Abdulrahman University, Riyadh-KSA
[2]Department of Scientific Computing, Faculty of Computer & Information Sciences, Ain Shams University, Cairo, Egypt

**Address for Correspondence**

Computer Science Department, College of Computer& Information Sciences, Princess Nora bint Abdulrahman University, Riyadh-KSA.
**E-mail:**
askhalifa@pnu.edu.sa

**ABSTRACT**

Rehabilitation is an important branch of health care that aims to restore some or all of the patient's physical, sensory, and/or mental capabilities that were lost due to injury, illness, or disease. With the increasing number of people with disabilities, more specialized rehabilitation staff and facilities are needed. However, evidence suggests that people with disabilities face barriers in accessing the health and rehabilitation services they need in many settings.
Therefore, Telerehabilitation has emerged as an evolutionary field of tele-medicine to overcome this availability problem by providing a wide range of consultative, preventative, diagnostic, and therapeutic services via the internet. Pairing these practices with game-based therapy has proved to increase their potential impact specially with pediatric populations. This paper gives a survey on some existing studies and suggests moving these telerehabilitation games into the cloud for the sake of convenience and flexibility.

**Keywords**: Cloud gaming, Tele-rehabilitation, Disabilities, Video games, Service.

## INTRODUCTION

The *World report on disabilities 2011*[1] estimated that around 15.6% persons 15 years and older live with a disability. People with childhood disabilities (0–14 years) are estimated to be 95 million (5.1%) children, of whom 13 million (0.7%) have "severe disability". In fact, there are many specific terms under that lead definition which guide the categorization of different types of such disabilities. For example,

Developmental delay may occur in one or more of those areas: Physical development, cognitive development, communication development, social and emotional development, and adaptive skills[2]. For example, a child having a physical developmental delay may have difficulties with gross motor skills - using the large muscle groups that assist in walking,

running, standing, sitting, changing positions and maintaining balance.

Here comes the importance of rehabilitation to restore some or all of the patient's physical, sensory, and mental capabilities that were lost due to injury, illness, or disease. Classically, the rehabilitation process starts with an assessment step to identify the nature of the patient's problem. This can then be followed by goal setting and intervention steps. Finally, an evaluation step should check on the effects of the deployed procedures[3].

Most of the intervention procedures are based on systematic activities or exercises that may result in a long boring therapy process[4]. A series of recent studies indicated action video games (AVG) as an innovative rehabilitation technology that can be utilized to improve patients' participation and motivation[5]. Most of these studies actually relied on virtual reality (VR) technologies[6] and; recently, game consoles such as Nintendo's Wii[7] or Microsoft's Kinect[8]. Although most of these studies depended on commercially available game packages that were usually available in rehabilitation facilities, some prototypes relied on specially designed games that can be played online[10]. This is usually referred to as tele-rehabilitation, where rehabilitation services can be accessed at a distance to solve problems such as availability and accessibility of resources[9]. With the availability of high speed networks and smart devices, these tele-rehabilitation games can be moved to the cloud enabling consumers to play anytime, anywhere without the hassle of downloads or complicated setup[12].

In this paper we will give a survey on the some successful studies highlighting the importance of telerehabilitation specially when implemented with game-based therapy. Furthermore, empowering these games with cloud services can be regarded as the future trend in this context. Therefore, the rest of this paper is organized as follows: section two gives a quick overview on the recent advances in cloud gaming. Next, in section three we review some of the studies that highlighted how game-based therapy can be effective and yet motivating for patients of different disabilities. In section four we are going to discuss how telerehabilitation can be the future trend when provided as a service through the clouds. Conclusions come finally in section five.

## What is cloud gaming?

Cloud computing can be considered the revolutionary technology of the current decade. It completely changed the way people use computers. Moving both data and applications to the cloud has transferred the computing perspective from the centralized fashion to a very flexible ubiquitous model[15]. Figure 1 shows the simple structure of the cloud computing infrastructure.

With the ability to access cloud services using almost any kind of device that can access the web, Cloud Computing achieves a number of advantages such as on-demand computing, portability, and flexibility. Such features was the key success factor for a lot of industries. Currently, Companies such as *Gaikai*[(1)], *CiiNOW*[(2)], *PlaycastMedia Systems*[(3)] and *OnLive*[(4)] are moving the gaming industry towards cloud-based applications as well.

In this context;"Cloud gaming", can be defined as a special type of online gaming that allows direct and on-demand streaming of games onto computers, consoles and mobile devices through the use of a thin client[16]. It takes advantage of a broadband connection, large server clusters, encryption and compression to stream game content to a client device. Users can play games without downloading or installing the actual game. In this scenario, the user

actions are transmitted directly to the server where the actual game code execution occurs and the server then sends back the game's response to the input controls.

After Nvidia unleashed its Game-as-a-Service (GaaS), virtualization and cloud computing hosts have been optimized not only for computing power, but also for graphics processing[17]. Furthermore, recent advances in streaming technology will take the gaming industry to the next level where it will be possible to deliver games directly to consumers through their smart televisions[13].

However, the main shortcoming of Gaming-as-a-Service is the network latency and connection speed needed to make the cloud gaming experience something equal to what is offered by dedicated game consoles. In this environment, latency is defined as Latency represents the time from a local user event (e.g., button press) to the user seeing the response on the screen[14]. In fact, a lot of factors actually contribute to the overall latency of a cloud-gamming system, as shown in figure 2. Since most cloud gaming platforms are closed and proprietary, their protocols of handling latency is still a great challenge for their competitors.

## Video games in rehabilitation therapies

The purpose of rehabilitation is to restore some or all of the patient's physical, sensory, and mental capabilities that were lost due to injury, illness, or disease. Classically, the rehabilitation process starts with an assessment step to identify the nature of the patient problem. This can then be followed by goal setting and intervention steps. Finally, an evaluation steps should check on the effects of the deployed procedures[3].

Rehabilitation can be generally classified into three main branches: preventive, medical, and socio-vocational rehabilitation. While the first two categories are more related to community awareness, Medical rehabilitation focuses mainly on dealing with persons with disabilities. It spans a number of areas such as: orientation, physical independence, occupational integration, mobility, social integration and so on[17].

Cognitive rehabilitation focuses on procedures and tools that help patients improve their problem solving skills in order to increase their awareness, productivity, and adaptability to the surrounding environment. One approach towards improving cognitive abilities is to engage a patient in systematic activities or exercises that are specially designed to improve a specific skill or ability[18]. Hence, specialists are challenged to find new ways to improve participation and motivation during the long therapy process. A series of recent studies has indicated that action video games (AVG) can be used effectively as a rehabilitative tool specially for pediatric populations[19]. Playing video games have promoted the potential ability to enhance memory, speed processing, boost executive functions, and/or augment fluid intelligence[20].

In fact, AVGs have been described as "one of the most innovative and promising recent developments in rehabilitation technology"[21]. Most of these tools use virtual reality (VR) technologies to create interactive simulations that embed and engage the user in realistic environments[22]. Other used game consoles such as Nintendo's Wii[7,6] (see figure 3).

The release of the Microsoft Xbox©-Kinect in 2010, has opened a lot of windows for interesting applications not only in the field of games but also in diverse areas such as robotics[23,24], ecological observation[25], behavioral studies[26], and more importantly physical therapy[27] and Rehabilitation[8].

Current research is being conducted to investigate the effects of using Xbox Kinect to assist patients with a wide variety of disabilities. A recent study[27] was carried out to investigate the effects of using Xbox Kinect on stroke survivors with hemiplegia.

The results showed a great improvement on upper extremity function compared to the control group that underwent conventional occupational therapy alone. Another study [8] showed that a Kinect-based system can be successfully utilized to reduce staff intervention and enhance participants' motivation, interest, and perseverance to engage in physical rehabilitation. More studies expanded the use of Microsoft Kinect motion sensor system to improve memory performance[28], and functional assessment[29]. However, most of these studies relied on commercially available games (see figure 3) rather than specially designed scenarios targeting more definite skills.

## Tele-Rehabilitation and the future trend

Telerehabilitation is a term that was first coined in 2002 at the State of Science Conference held in USA[30]. Telerehabilitation can be defined as the delivery consultative, preventative, diagnostic, and therapeutic services via the internet[9]. Some fields of rehabilitation practice have explored telerehabilitation such as: neuropsychology, speech-language pathology, audiology, occupational therapy, and physical therapy. However, its effectiveness still depends upon the specifics of the application, including the type and severity of disability, purpose of assessment, intervention goals, specifics of the technology, and infrastructure of both the local and remote sites.

Research in the field of telerehabilitation is rapidly growing through the past few years. Several methods of intervention have been proposed. Earlier studies explored using videoconferencing in intervention planning[31] and consultation[32]. virtual Reality was also proposed as a telerehabilitation approach. The authors in[33] explored and discussed early scenarios of Internet deliverable VR applications for home-based therapy and rehabilitation. Other research proposed using an Internet-based

multi-touch sensor interface to develop a product for brain-injured patients[34]. The study investigated enabling motivated play with games, music, and painting to supplement traditional rehabilitation training methods.

In[35], the authors presented a complete telerehabilitation system to quantitatively assess gait patients' progress in and outside the hospital. The complete system presents itself as a portable kit able to furnish feedback on parameters that are useful to both the patient and the trainer/therapist. This represents a novel approach for gait monitoring based simply on a step-counter (pedometer); photo-emitter/detectors (at the initial, intermediate, and final path stations); a central unit for collecting and processing the telemetrically transmitted data; and a software interface. The system is capable of integrating with the most common tools used in motion rehabilitation (e.g., handrails, scales, walkways), and can quantitatively assess and monitor patients' progress in rehabilitation. Case studies showed that the portable kit is both feasible and well-accepted. Possible advantages include: (a) low costs, especially when compared to optoelectronic or other portable solutions; (b) high accuracy; (c) benefits to subjects with balance problems; and (d) integration (compatibility) with any rehabilitative tool.

An ongoing research in Germany's Fraunhofer Institute for Open Communication Systems FOKUS is focusing on taking rehabilitation games one step further. As shown in figure 4, using a Kinect camera and built-in software, a "telerehabilitation" system allows patients to perform exercises at a distance while still receiving feedback from a physiotherapist[10]. The software sends data collected on the patient's movements to the physiotherapist via the internet. The physiotherapist can then dynamically increase the intensity of the exercises based on the patient's progress.

## CONCLUSIONS

Despite the statistics indicating that the number of people with disabilities is growing all over the world, less attention is being given to providing accessible quality rehabilitation services. Telerehabilitation can be the cost-effective alternative to deliver these services at a distance in order to overcome the difficulties that may prevent a patient from receiving care at a clinic. Pairing these intervention procedures with gaming technology has proved to be more effective and motivating.

Moving these tele-rehabilitation games to the cloud can be considered as the future challenge in this field. That is, itcan further increase their potential benefits by providing a centralized pole of services that are accessible using any PC, tablet or TV over the Internet at a massively reduced cost. However, this imposes great challenges regarding the game quality and the latency associated with interactive video streaming. Another importantly related issue is the security of the system in terms of privacy and confidentiality of patients' information.

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(1)**Gaikai** is a company which provides technology for the streaming of high-end video games. Founded in 2008 and was acquired by Sony Computer Entertainment in 2012. It is specialized in in-home streaming (as in Remote Play between the PlayStation 4 and PlayStation Vita), as well as cloud-based gaming (such as the PlayStation Now game streaming service).

(2)**CiiNOW** was founded in 2010 now receiving major funding from Alcatel-Lucent and AMD. The biggest advantage of CiiNOW Cloud Gaming Platform is its super low latency.

(3)**Playcast Media Systems** was founded in 2007 and considered among the first gaming-on-demand technology services for Cable and IPTV in the world provides a gaming on demand service. It has partnerships with some of the largest video game publishers in the world, including: Activision, Atari, Disney, Capcom, Codemasters, THQ and Strategy First.

(4)**OnLive** is a company offering a cloud gaming platform and a cloud desktop system. It was announced at the Game Developers Conference in 2009. OnLive's original investors include Warner Bros., Autodesk, Maverick Capital, AT&T Media Holdings, Inc., British Telecom and Belgacom.

## REFERENCES

1. "World report on disabilities," World Health Organization, Geneva, 2011.
2. D. f. E. Childhood, "Concept Paper on Developmental Delay," Council for Exceptional Children, November 2001.
3. Tony Ward and Shadd Maruna, Rehabilitation, Routledge, 2007.
4. Peter W. Halligan and Derick T. Wade, The Effectiveness of Rehabilitation for Cognitive Deficits, 2005: Oxford University Press Inc., New York.
5. Weiss PL, Rand D, Katz N, Kizony R, "Video capture virtual reality as a flexible and effective rehabilitation tool," _J Neuroeng Rehabil_, p. 1:12, 2004.
6. Yasser Salem, Stacy Jaffee Gropack, Dale Coffin, Ellen M. Godwin, "Effectiveness of a low-cost virtual reality system for children with developmental delay," _Physiotherapy_, vol. 98, p. 189–195, 2012.
7. Harrison L. Bartlett, Lena H. Ting, Jeffrey T. Bingham, "Accuracy of force and center of pressure measures of the Wii Balance Board," _Gait & Posture_, vol. 39, p. 224–228, 2014.
8. Chang, Y., Han, W., & Tsai, Y. , "A Kinect-based upper limb rehabilitation system to assist people with cerebral palsy," _Research In Developmental Disabilities_, vol. 34, no. 11, pp. 3654-3659, 2013.
9. "Physiotherapy Software allows control of home-patients," 28 January 2013. [Online].
10. "Telerehabilitation Position Paper," _The American Journal of Occupational Therapy_, vol. 59, no. 6, pp. 656-660, December 2005.
11. "NVIDIA GRID revealed to change cloud gaming forever," 6 January 2013. [Online]. Available: http://www.slashgear.com/nvidia-grid-revealed-to-change-cloud-gaming-forever-06263511/.
12. Rabindra K. Jena, P. K. Mahanti, "Computing in the Cloud: Concept and Trends,"

*International Review on Computers and Software*, vol. 6, no. 1, pp. 1-10, 2011.

13. Shea, Ryan; Jiangchuan Liu, Edith C.-H. Ngai, Yong Cui, "Cloud Gaming: Architecture and Performance," IEEE Network, pp. 16-21, July–August 2013.

14. S. Beaver, "Gaming as a Service," The Virtualization Practice, 18 April 2013.

15. G. Winslow, "The TV games," B R O A D C A S T I N G & C A B L E, pp. 12-13, 11 N OV E M B E R 2013.

16. R. Sharp, "Latency in Cloud-Based Interactive Streaming Content," *Bell Labs Technical Journal*, vol. 17, no. 2, p. 67–80, 2012.

17. S. Sunder, Textbook of Rehabilitation, New Delhi: Jaypee Brothers Publishers, 2004.

18. Peter W. Halligan and Derick T. Wade, The Effectiveness of Rehabilitation for Cognitive Deficits, New York: Oxford University Press Inc, 2005.

19. Jennifer Howcroft, Sue Klejman, Darcy Fehlings, Karl Zabjek, Jan Andrysek, and Elaine Biddiss, "Active Video Game Play in Children with Cerebral Palsy: Potential for Physical Activity Promotion and Rehabilitation Therapies," *Archives of Physical Medicine and Rehabilitation*, vol. 93, 2012.

20. C.S. Green, and D. Bavelier, " Learning, Attentional Control, and Action Video Games," *Current Biology*, vol. March 20, p. R197–R206, 2012.

21. Weiss PL, Rand D, Katz N, Kizony R., "Video capture virtual reality as a flexible and effective rehabilitation tool," *Neuroeng Rehabil*, pp. 1 - 12, 2004.

22. Danielle E. Levac, a Jane Galvin, "When Is Virtual Reality ''Therapy''?," *Archives of Physical Medicine and Rehabilitation*, vol. 94, pp. 795-798, 2013.

23. Guanglong, D., Ping, Z., Jianhua, M., & Zeling, L., " Markerless Kinect-Based Hand Tracking for Robot Teleoperation," *International Journal Of Advanced Robotic Systems*, pp. 91-110, 2012.

24. Muis, A., & Indrajit, W., "Realistic Human Motion Preservation-Imitation Development on Robot with Kinect," *Telkomnika*, vol. 10, no. 4, pp. 599-608, 2012.

25. Azzari, G., Goulden, M. L., & Rusu, R. B. , " Rapid Characterization of Vegetation Structure with a Microsoft Kinect Sensor," *Sensors*, vol. 13, no. 2, pp. 2384-2398, 2013.

26. Seer, Stefan, Norbert Brändle, and Carlo Ratti, "Kinects and Human Kinetics: A New Approach for Studying Crowd Behavior.," 2012. [Online]

27. HyeonHui, S., & GyuChang, L, "Additional Virtual Reality Training Using Xbox Kinect in Stroke Survivors with Hemiplegia," *American Journal Of Physical Medicine & Rehabilitation*, vol. 92, no. 10, pp. 871-880, 2013.

28. Kuo-Jen Chao, Hui-Wen Huang, Wei-Chieh Fang , Nian-Shing Chen, "Embodied play to learn: Exploring Kinect-facilitated memory performance," *British Journal of Educational Technology*, vol. 44, no. 5, pp. pE151-E155, . Sep2013.

29. Bonnechère, B. Jansen, B, Salvia, P., Bouzahouene, H., Omelina, L., Moiseev, F., Sholukha, V., Cornelis, J., Rooze, M., Van Sint Jan, S, "Validity and reliability of the Kinect within functional assessment activities: Comparison with standard stereophoto-grammetry," *Gait & Posture*, vol. 39, no. 1, pp. 593-598, Jan 2014.

30. Winters JM, Lathan C, Sukthankar S, Pieters TM, Rahman T, " Human Performance and Rehabilitation Technologies," in Biomechanics and Neural Control of Movement, New York , Springer-Verlag, 2001, pp. Chapter 37, 493-51.

31. Guilfoyle, C., Wootton, R., Hassall, S., Offer, J., Warren, M., & Smith, D., "Preliminary experience of allied health assessments delivered face to face and by videoconference to a residential facility for elderly people," *Journal of Telemed Telecare*, vol. 9, p. 230–233, 2003.

32. Cooper, R., Fitzgerald, S., Boninger, M. L., Cooper, R. A., Shapcott, N., Cohen, L. et al., "Using telerehabilitation to aid in selecting a wheelchair," RESNA Annual Conference Proceedings, p. 245–247, 2002.

33. Albert A. Rizzo, Dorothy Strickland, and Stéphane Bouchard, "The Challenge of Using Virtual Reality in Telerehabilitation," *Telemedicine Journal and e-Health*, vol. 10, no. 2, 2004.

34. A. L. Brook, "Tele Abilitation: Game Abilitation," in Telerehabilitation, London, Springer, 2013, pp. 225-237.
35. Daniele Giansanti, Sandra Morelli, Paco Dionisio, Giovanni Maccioni, "Design, Construction, and Integration in Instrumented Walkways of a Portable Kit for the Assessment of Gait Parameters in Telerehabilitation," in Telerehabilitation, London, Springer, 2013, pp. 263-274.
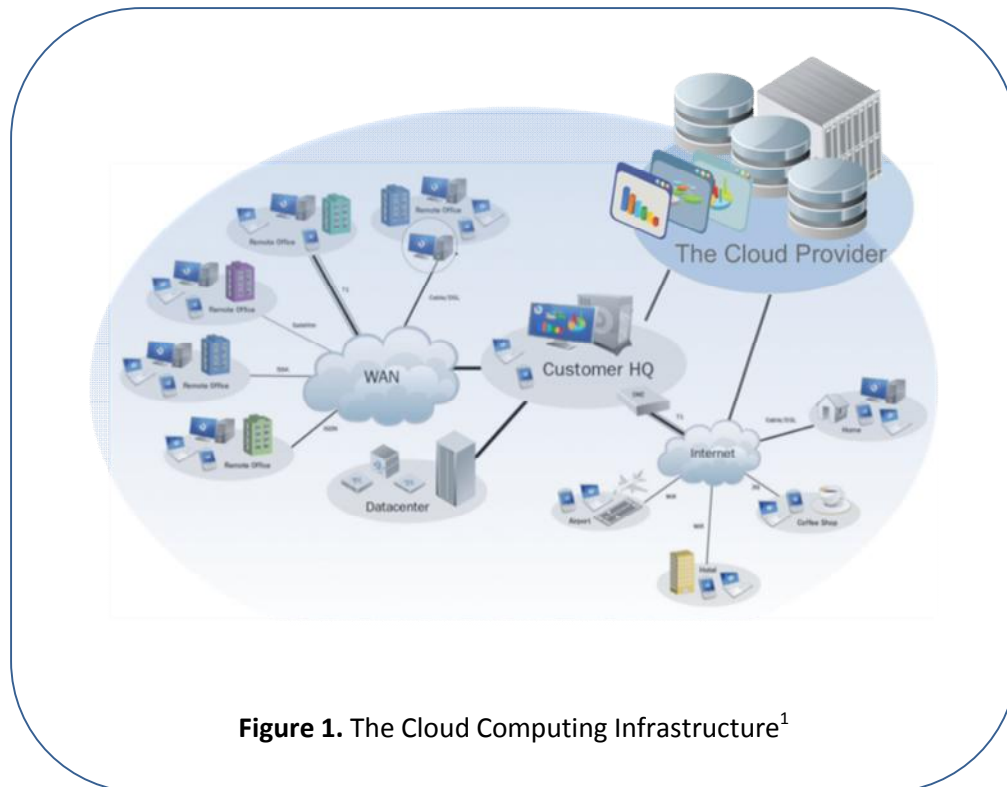
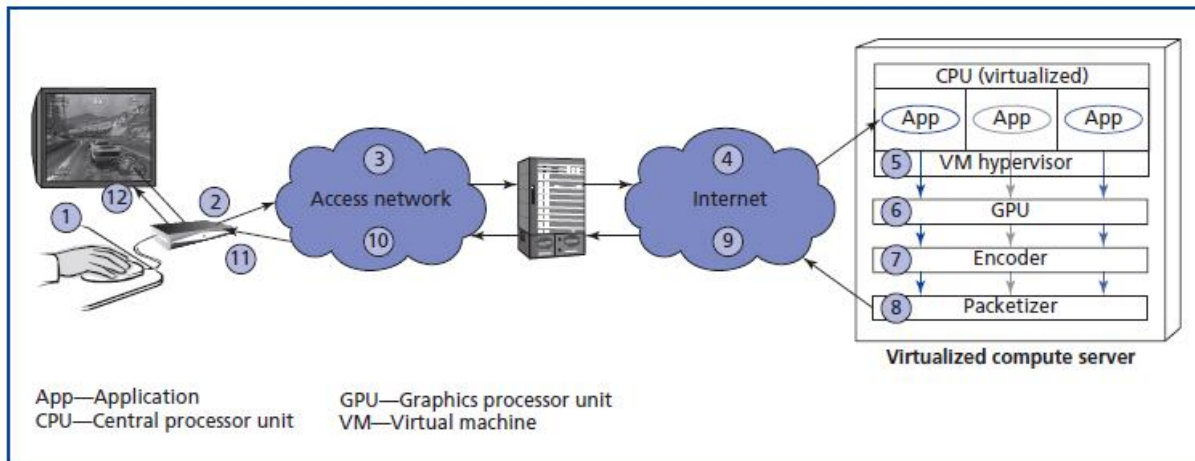**Figure 1.** The Cloud Computing Infrastructure[1]

[1]http://www.c3dmw.com/IRDC3DMW/CloudComputing.jsp

**Figure 2.** Round Trip Latency Path[14]



**(a)** Using the Wii Fit soccer heading game[7]          **(b)** Games for helping burn patients[6]

**Figure 3.** Using Wii game consoles as a rehabilitative tool

**Figure 4.** Fraunhofer's telerehabilitation system in use