Handbook of Research on Holistic Perspectives in Gamification for Clinical Practice

Daniel Novák
Czech Technical University in Prague, Czech Republic

Bengisu Tulu
Worcester Polytechnic Institute, USA

Håvar Brendryen
Norwegian Center for Addiction Research, University of Oslo, Norway

A volume in the Advances in Medical Technologies and Clinical Practice (AMTCP) Book Series

Medical Information Science
REFERENCE
An Imprint of IGI Global

Managing Director:	Lindsay Johnston
Managing Editor:	Keith Greenberg
Director of Intellectual Property & Contracts:	Jan Travers
Acquisitions Editor:	Kayla Wolfe
Production Editor:	Christina Henning
Cover Design:	Samantha Barnhart

Published in the United States of America by
Medical Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

CIP Data Pending
ISBN: 978-1-4666-9522-1
eISBN: 978-1-4666-9523-8

This book is published in the IGI Global book series Advances in Medical Technologies and Clinical Practice (AMTCP) (ISSN: 2327-9354; eISSN: 2327-9370)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Chapter 9

Using Leap Motion and Gamification to Facilitate and Encourage Rehabilitation for Hand Injuries:

Leap Motion for Rehabilitation

Jamie Taylor
University of Kent, UK

Kevin Curran
University of Ulster, UK

ABSTRACT

Injuries to the hand are more common than those of any other body region and can have considerable financial, time-measured and psychological impact on not only the victim but also the community as a whole. Hand rehabilitation aims to return people to their pre-injury roles and occupations and has proved largely successful in doing so with the potential for technology to improve these results further. However, most technology used in hand rehabilitation is based on expensive and non-durable glove-based systems and issues with accuracy are common among those that are not glove-based. This chapter proposes the use of accurate, affordable and portable solutions such as the Leap Motion as a tool for hand rehabilitation. User feedback can be provided primarily through an animated 3d hand model as the user performs rehabilitative exercises.

INTRODUCTION

At present, it is common for individuals with hand injuries to undergo rehabilitation using no technical aids. Efforts to improve rehabilitation through the use of technology have led to a number of systems being proposed, where most of these systems are glove-based, with only a few alternatives. The glove-based systems are (for the most part) prohibitively expensive (O'Donnell, 2010), and the few alternatives such as Kinect (Connolly, 2012) can suffer from portability and accuracy

DOI: 10.4018/978-1-4666-9522-1.ch009

issues. It should also be noted that none of these system take advantage of gamification. Gamification is the use of game-like elements in traditionally non-game like settings, and has been proven to increase user enjoyment and participation.

In response to this need for new rehabilitation technologies, this chapter suggests that there is scope for motion-based systems such as the newly released Leap Motion[1] to assist in rehabilitation.

This chapter outlines the potential for such a system to assist in hand rehabilitation. We believe that the Leap Motion, a new, recently released motion-based device has yet to be investigated as a tool for hand rehabilitation. We suggest that it should be accompanied by a software in the form of an animated 3D hand model which will reflect the users hand movements in real-time. The results from the exercises can then be stored for later viewing by either the patient or a clinician. Furthermore, the addition of gamification elements to the proposed system can help encourage patients to adhere to prescribed exercise programs. We next investigate current techniques and technologies used in the field of hand rehabilitation to better inform the design of such a motion-based capturing system.

BACKGROUND

Hand rehabilitation therapy is a form of occupational therapy (Burke, 2009). Hand rehabilitation/therapy is focused on "…enabling the client to regain functional use of the traumatized arm and hand … and return to their pre-injury occupations." (Case-Smith, 2003). The treatment offered by hand therapy can be divided into two main categories; these are preventative, non-operative and post-operative. Using the information presented in (American Society for Surgery of the Hand, 2011), a more complete list of treatment options offered through hand therapy can be compiled and is presented in Table 1.

Of the treatments listed above, it is "design and implementation of home exercise programs…" and "instruction in home exercise programs" that are of particular relevance and interest. (Lavanon, 2013) Points out that such hand therapy exercises should be "motivating, repetitious, interesting, challenging and graded", (Amini, 2011) adds that these exercises should incorporate "usual and customary occupation activities…", this is important, given that the aim of hand therapy as described above is to return patients to their occupational and pre-injury roles. At present, it is common for home exercise programs to be performed without the use of technological aids or systems. Hand therapy offers a high success rate as a treatment for hand injuries. Of those studied and treated in (Case-Smith, 2003), 80% returned to work after an 8-week course of treatment consisting of 13 hours of treatment on average. These results are of particular relevance because during this time, the occupational therapist was the patient's sole provider of rehabilitation ser-

Table 1. Non-Operative/Postoperative Hand Therapy Treatments

Preventative, Non-Operative, Conservative	Postoperative Rehabilitation
Management of acute or chronic pain	Management of open or sutured wounds
Desensitization following nerve injury or trauma	Control of hypertrophic or hypersensitive scars
Sensory re-education after nerve injury	Reduction of swelling
Design and implementation of home exercise programs to increase motion, dexterity and/or strength	Fabrication of orthoses to protect surgery or increase movement
Training in performance of daily life skills through adapted methods and equipment	Instruction in home exercise program
Splint fabrication for prevention or correction of injury	
Conditioning prior to returning to work	

vices, showing that hand rehabilitation/therapy even in isolation can be greatly successful and beneficial.

While hand therapy is already a successful form of treatment for hand injuries (Case-Smith, 2003), Lavanon (2013) argues that advanced technology can enrich this form of treatment and further help patients. Looking in more detail, we see that technology can be applied to other areas of hand injury treatment beyond rehabilitation. The CODA motion analysis system[2] can be used as a diagnostic motion analysis tool. More relevant to this discussion however, is the use of technology as a rehabilitative tool, in particular, the use of everyday "off the shelf" technology such as the Leap Motion. An example of such a system is described in (Lavanon, 2013), where a Virtual Reality (VR) system was constructed using the PlayStation EyeToy, a common consumer device. The EyeToy based system was found to be an effective and – more importantly – enjoyable way of exercising, however the system failed to grade exercises. We aim to implement grading of exercises in the proposed system, and plan to enhance it further through the introduction of gamification elements.

Glove-based technology, specifically data-glove technology, is arguably the most common form of technological aid in treatment and managing of hand injuries. Example applications include motor assessment (Lautman, 2012) and as a tool for rehabilitative exercises (O'Donnell, 2010). Dipietro, et al. (2008) defines glove-based technology as "a system composed of an array of sensors, electronics for data acquisition/processing, power supply and a support for sensors that can be worn on the user's hand." Such gloves are typically made of Lycra onto which sensors are sewn. These sensors then record data of the wearer's hand movements, joint movement, fingertip positioning and so forth. One example is the 5DT Data Glove Ultra developed by Fifth Dimension Technologies (Fifth Dimension Technologies, 2011), a data glove aimed primarily at Motion Capture and Animation Professionals. The glove has a total of 14 sensors, uses proprietary optical-fiber flexors and supports 2^4=16 possible gestures (Dipietro, et al., 2008). The glove communicates with a computer via USB cable or RS 232 serial port through an additional kit (sold separately); another kit is available to allow for wireless operation via Bluetooth (also sold separately), allowing 8 hours of use on a single battery at a range of up to 20 meters. The glove itself costs about $1000; this includes the glove and the 'GloveManager' proprietary calibration software. The 5DT Data Glove Ultra is available in left and right variants. The high adoption rate of glove-based technology is primarily due to the richness of the information provided by such systems (Dipietro, et al., 2008).

GAMIFICATION

The Leap Motion (mass shipping began July 2013), shown in Figure 1, is a motion-based device for computer interaction developed by Leap Motion Inc. (Leap Motion Inc, 2013) who claim the device offers accuracy to within 0.01mm. The device, as shown in Figures 1 and 2, is made up of two monochromatic IR cameras (the grey dots in Figure 2) and three infrared LEDs (the red dots in Figure 2), giving the device a semi-spherical observational area with a distance of approximately 1 meter. This observational area is smaller than that of the Kinect, which is designed to monitor the entire body; however, this allows the Leap Motion to operate at a higher resolution and accuracy where accuracy is defined as the ability of a 3D sensor to determine a desired position in 3D space. The IR cameras can run at up to 300 frames per second (as opposed to 30 with the Kinect) while the LEDs generate a 3D pattern of dots made up of IR light. A study on the accuracy of the Leap Motion found that while the claimed 0.01mm ac-

Figure 1. Leap Motion

curacy is not achievable, a high precision accuracy of 0.7mm was achievable (Weichert, et al., 2013). This makes the Leap far superior to the standard deviation of 1.5cm (15mm) found in the Kinect.

In addition to the technical improvements, the Leap Motion enjoys other benefits over previous systems. Firstly, the Leap Motion is more affordable than any other device discussed in this chapter - even the Kinect (sold for UK Sterling £75 in 2014) - the Leap Motion is available for £65 UK Sterling as of 2014. The Leap Motion also benefits from its small size, coming in at 0.5 inches in height, 1.2 inches in width and 3 inches in depth with a weight of only 0.1 pounds (Leap Motion, 2013), making it more portable than any other device discussed in this chapter. Another advantage of the Leap Motion, one that also applies to Kinect, is its durability; the Leap Motion is not prone to wear and tear that eventually claims many glove-based system. A large community has been cultivated around Leap Motion. Apps are being released as well. There is also

Figure 2. Leap Motion Schematic View

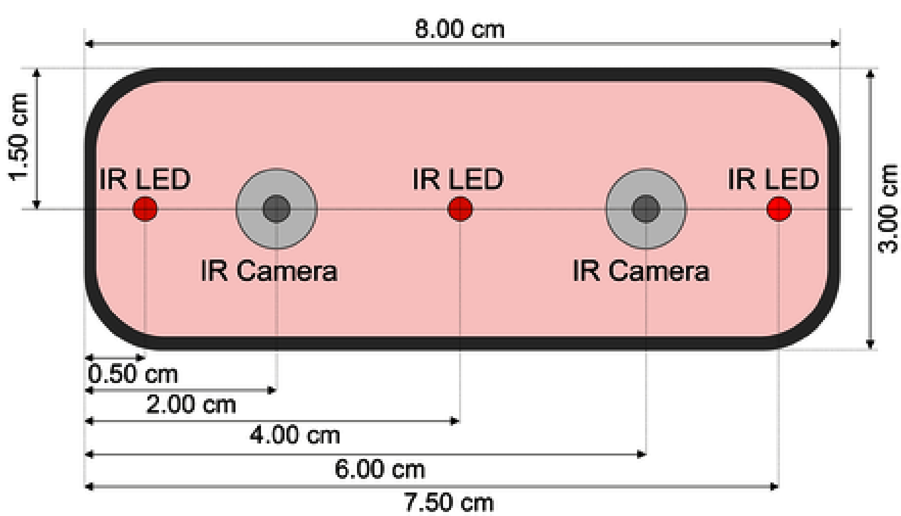
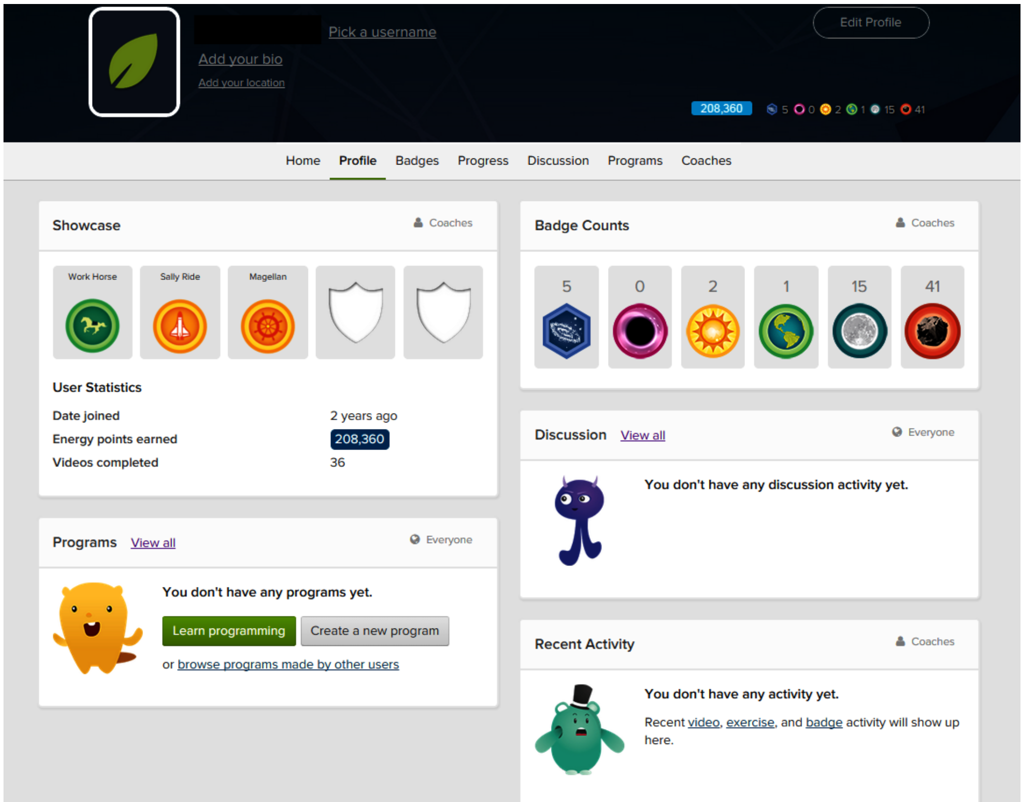


Figure 3. Stat Tracking and Achievement System



integration of the leap motion into laptops from leading retailers such as HP and Dell and into VR headsets. There is a momentum behind the leap motion and this could propel it into the de facto gesture recognition interface in the near future.

Gamification can be defined as "the use of game design elements in non-game contexts" (Deterding, et al., 2011). Gamification is a fast growing initiative, with the aim of increasing motivation and participation among users of non-game applications and is expected to revolutionize all aspects of life in the not too distant future (Chatfield, 2010), (The Pleasure Revolution: Why Games Will Lead the Way, 2011). An ideal example of game design elements being used in a non-game context would be the Khan Academy (Khan Academy, 2013). The Khan Academy is a non-profit organization with the aim of providing "a free world-class education for anyone anywhere". The site allows users to watch videos on a wide variety of educational topics, complete exercises for which they can build up streaks, earn badges and a Gamerscore-like collection of points in addition to an array of real-time stat tracking tools as seen in Figure 3.

More relevant to this discussion however, is the use of gamification in a medical and rehabilitation setting. Gerling & Masuch (2011) explore the application of gamification in augmenting the lives of frail elderly people who are no longer able to participate in certain real-life activities due to age (such as a recreational walk through a forest) as shown in Figure 4. They suggest that if we are able to overcome challenges such as the lack of experience with digital games and systems then elderly users can benefit not only cognitively and physically thanks to increased participation in therapeutic activities, but also socially from the experience, as gamified applications offer the opportunity for friendly competition.

Figure 4. Gamified Application - Walking through a Forest

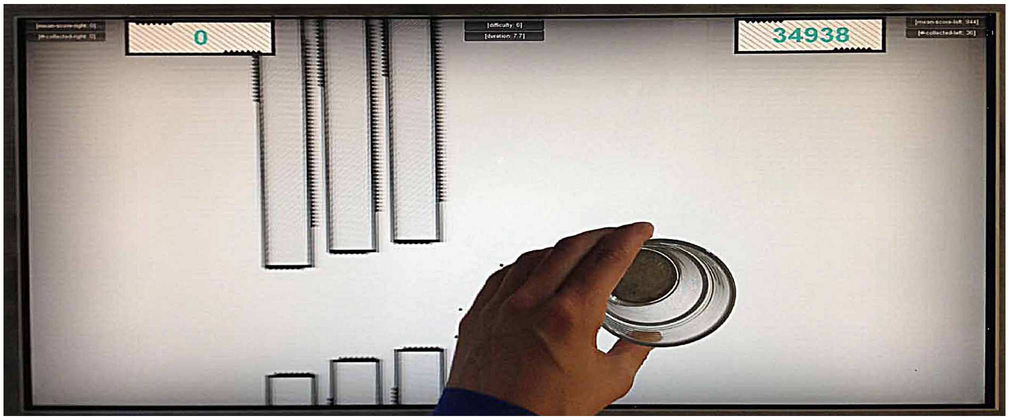
Gamification and 'gamified applications' like serious games have been proven to work in medical undertakings such as stroke rehabilitation. Burke, et al. (2009), after looking at the use of gamified applications in helping those affected by strokes regain control of the affected limbs, concluded that gamified applications can be used to help solve a common issue experienced by many stroke survivors undergoing therapy. The issue being that the everyday actives assigned to them as part of their rehabilitative therapy are boring and uninteresting. Couple this with the depression that is common among stroke survivors and the result is low user enthusiasm, low participation and poor results in terms of limb functionality regained through therapy. The study proves that gamification can make activities these engaging and stimulating, encouraging user participation and by extension, leading to better results in terms of regained functionality.

The study that is of most relevance however is that conducted by Jacobs, et al. (2013), where the authors investigate the use of gamified applications in arm-hand training for stroke survivors. Here, a proprietary 'serious game' (a form of gamified application) named CONTRAST, shown in Figure 5 was used wherein the user completes task-oriented exercises involving the manipulation of everyday items. Results of the study show increased user participation and by extension, improved arm-hand functionality. They point out that gamified applications make rehabilitative exercises "meaningful". However, research would suggest that gamification has yet to be used in a hand-rehabilitation setting despite the fact that both hand rehabilitation and gamification place emphasis on identifying the user/patients personal goals "incorporating usual and customary occupational activities into treatment…" (Amini, 2011), likewise, making the experience relevant to the user is also an essential part of gamification "… it is important to catch the user's personal goals…" (Groh, 2012).

FUTURE RESEARCH DIRECTIONS

Gartner predicts that 50 percent of corporate innovation will be gamified, with American corporations spending several billion dollars on it in the next 12 months[3]. Healthcare domain can also benefit from gamified innovations, as many problems faced in healthcare can benefit from solutions that utilize gamification. The younger generation is quite au fait with gaming so introducing gamification into clinical settings may lead to cleaner measurements in some groups from specific demographics.

Figure 5. User completing a task-oriented exercise in a Serious Rehabilitation Game



Leap Motion is an example of such gamified solutions. Unlike traditional data-gloves, the Leap Motion easily allows for two-handed exercises and potentially exercises involving items such as cups or other everyday items (through the SDK "point-able" object which allows for tracking of additional items, not just fingers). At the moment, however, the Leap Motion SDK does not offer skeletal tracking which makes any work with the device inherently more difficult than with traditional data gloves. Effort should be made to implement a means by which individual fingers can be reliably identified, as this will ultimately allow for more accurate readings and the addition of more complex and intricate exercises.

CONCLUSION

This chapter outlines the potential of a Leap Motion rehabilitation system for those with hand injuries rather than more traditional technologies like data-gloves. Such a system would allow a user to perform rehabilitative exercises while receiving stimulating feedback via a real-time animated model. The system can easily store this data for later viewing by either the patient or a clinician. The Leap Motion is not in itself a groundbreaking technology but its power lays in the affordable price that it is currently retailing at. There are currently HP laptops that come with the leap motion installed. We can expect to see more similar systems arriving on the market therefore a potential arises to exploit this relatively cheap movement tracking system in the healthcare system. We truly believe that the price and relative accuracy of this device in addition to its other unique qualities mean the Leap Motion has enormous potential in rehabilitation systems of the 21st century.

REFERENCES

Hand and Arm Conditions. (2011). *American Society for Surgery of the Hand*. Retrieved from http://www.assh.org/Public/HandConditions/Pages/HandTherapy.aspx

Amini, D. (2011). *The Unique Role of Occupational Therapy in Rehabilitation of the Hand Journal of Hand Therapy*, *28*, 19–34.

Burke, J., McNeill, M., Charles, D., Morrow, P., Crosbie, J., & McDonough, S. (2009). Optimizing Engagement for Stroke Rehabilitation using Serious Games. *The Visual Computer*, *25*(12), 1085–1099. doi:10.1007/s00371-009-0387-4

Case-Smith, J. (2003). Outcomes in Hand Rehabilitation Using Occupational Therapy Services. *The American Journal of Occupational Therapy*, *57*(5), 499–506. doi:10.5014/ajot.57.5.499 PMID:14527111

Chatfield, T. (2010). *Why Gaming Will Dominate the Twenty-First Century*. Pegasus.

Codamotion (2015). Retrieved from http://www.codamotion.com/

Condell, J., Curran, K., Quigley, T., Gardiner, P., McNeill, M., & Winder, J. et al. (2012). Finger Movement Measurements in Arthritic Patients Using Wearable Sensor Enabled Gloves. International Journal of Human Factors Modelling and Simulation, Special Issue on. *Digital Human Modelling for Wearable Products*, *2*(4), 276–292.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). *From Game Design Elements to Gamefulness: Defining "Gamification"*. Mindtrek. doi:10.1145/2181037.2181040

Dipietro, L., Sabatini, A. M., & Dario, P. (2008). A Survey of Glove-Based Systems and their Applications. *IEE Transactions of Systems, Man, and Cybernetics*, *38*(4), 461–482. doi:10.1109/TSMCC.2008.923862

Gerling, K. M., & Masuch, M. (2011). Exploring the Potential of Gamification among Frail Elderly Persons. Vancouver, Groh, F., 2012. Research Trends in Media Informatics: Gamification: State of the Art Definition and Utilization. pp. 39-46.

Jacobs, A., Timmermans, A., Michielsen, M., Plaetse, M., & Markopoulos, P. (2013). CONTRAST: Gamification of Arm-Hand Training for Stroke Survivors. Proceedings of CHI EA '13 Extended Abstracts on Human Factors in Computing Systems (p. 415-420).

Jakobsson, M. (2011). *The Achievement Machine: Understanding Xbox 360 Achievements in Gaming Practices*. Retrieved from http://gamestudies.org/1101/articles/jakobsson

O'Donnell, B. (2010). *Hand Rehabilitation Using a Peregrine Gaming Data Glove, Londonderry*. University of Ulster.

Lavanon, Y. (2013). The Advantages and Disadvantages of using High Technology in Hand Rehabilitation. *Journal of Hand Therapy*, *26*(2), 179–183. doi:10.1016/j.jht.2013.02.002 PMID:23598084

Leap Motion Product Page. (2013). Leap Motion Inc. Retrieved from https://www.leapmotion.com/product

Weichert, F., Bachmann, D., Rudak, B., & Fisseler, D. (2013). Analysis of the Accuracy and Robustness of the Leap Motion Controller. *Sensors (Basel, Switzerland)*, *13*(5), 6380–6393. doi:10.3390/s130506380 PMID:23673678

ADDITIONAL READING

Dias, J. J. & Garcia-Elias, M., 2006. Hand Injury Costs. INJURY - International Journal of the Care of the Injured, 37(11), pp. 1071-1077.

G, R. (2003). Couts des Urgences Mains. Chir Main, 22, 258-263.

Hasselkus, B. (2002). *The Meaning of Everyday Occupation*. NJ: Slack Inc.

Hillerbrand, G., Bauer, M., Achatz, K., & Linker, G. (2005). *Inverse Kinematic Infrared Optical Finger Tracking*. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.62.9632&rep=rep1&type=pdf

Holmberg, J., Lindgren, B., & Jutemark, R. (1996). Replantation-Revascularization and Primary Amputation in Major Hand Injuries. Resources Spent on Treatment and the Indirect Costs of Sick Leave in Sweden. *The Journal of Hand Surgery*, *21*(5), 576–580. doi:10.1016/S0266-7681(96)80134-3 PMID:9230937

Lautman, R. (2012). *Assessing Hand Movement i Arthritic Patients Using Wearable Glove Technology*. Londonderry.

SDK Documentation - Tracking Hands. (2013). Leap Motion. Retrieved from https://developer.leapmotion.com/documentation/python/devguide/Leap_Tracking.html

Nyko Zoom for Kinect Review. (n. d.). Pc Mag. Retrieved from http://xbox.about.com/od/projectnatal/fr/Nyko-Zoom-For-Kinect-Review-X360-Kinect.htm

Peregrine Product Page. (n. d.). Peregrine. Retrieved from http://theperegrine.com/product/

Shneiderman, B. P. C. (2005). *Designing the User Interface* (4th ed., pp. 92–93). Pearson.

Sommerville, I. (2010). Software Engineering (9 ed.). Addison Wesley.

Sousa, A. D., Sonavane, S., Kurvey, A., Kukreja, K., Shah, N. (2013). Psychological issues in hand trauma. *ASEAN Journal of Psychiatry*, 14(1).

Ergonomics and Repetitive Strain Injury. (2008). Strategy One for Microsoft.

Schell, J. (2011. The Pleasure Revolution: Why Games Will Lead the Way) [Film].

Trybus, M., Lorkowski, J., Brongel, L. & Hladki, W. (2006). Causes and Consequences of Hand Injuries. *The American Journal of Surgery*, July; 129(1), 52-57.

Turner, J. R. (1993). *The Handbook of Project-Based Management*. McGraw-Hill Book Co.

Willow Garage Home Page. (2011). Willow Garage. Retrieved from http://www.willowgarage.com/

Yassi, A. (1997). Repetitive Strain Injuries. *Lancet*, *349*(9056), 943–947. doi:10.1016/S0140-6736(96)07221-2 PMID:9093264

KEY TERMS AND DEFINITIONS

Data Glove: A glove which can be connected through a wire or wirelessly to a computer (or mobile device) to record movement. Glove vary in accuracy and this is usually in accordance with the price.

EyeToy: The EyeToy is a color digital camera device, similar to a webcam, for the PlayStation 2. The technology uses computer vision and gesture recognition to process images taken by the camera. This allows players to interact with games using motion, color detection and also sound, through its built-in microphone. It was released in October 2003.

Gamification: Gamification is the use of game-like elements in traditionally non-game like settings and has been proven to increase user enjoyment and participation.

Hand Rehabilitation: Hand rehabilitation aims to return people to their pre-injury roles and occupations and has proved largely successful in doing so with the potential for technology to improve these results further.

Leap Motion: The Leap is a recently released motion-based device for computer interaction developed by Leap Motion Inc. offering accuracy to within 0.01mm. The device is made up of 2 monochromatic IR cameras and 3 infrared LEDs giving the device a semi-spherical observational area with a distance of approximately 1 meter.

Motion Capture: This is the process of recording the movement of objects or people. It is used in military, entertainment, sports, and medical applications, and for validation of computer vision and robotics. In filmmaking and video game development, it refers to recording actions of human actors, and using that information to animate digital character models in 2D or 3D computer animation.

Rehabilitation Counseling: Is focused on helping people who have disabilities achieve their personal, career, and independent living goals through a counseling process.

ENDNOTES

1 https://www.leapmotion.com/

2 http://www.codamotion.com/

3 http://www.gartner.com/newsroom/id/1629214.