Chapter 49
Glove-Based Technology in Hand Rehabilitation

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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 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 which are not glove-based. The authors outline an accurate, affordable and portable solution wherein the authors use the Leap Motion as a tool for hand rehabilitation. User feedback will be given primarily through an animated 3d hand model as the user performs rehabilitative exercises. Exercise results will be recorded for later viewing by patients and clinicians. The system will also include Gamification aspects, techniques which (while proven to increase participation) have seen little to no use in hand-rehabilitation systems.

1. INTRODUCTION

The human hand is one of the most complex creations in existence and the main enabler of our modern lifestyles. Given this intense and extensive use, it should come as little surprise that injuries to the hand are more common than those of any other body region (Trybus, et al., 2006). Injuries such as Repetitive Stress Injuries (RSI's), lacerations and crushing are just a few common injuries to hand. Such injuries are treated through hand rehabilitation (Amini, 2011). This includes measures such as splinting the hand and prescribing rehabilitation exercises designed to strengthen the muscles in the hand and prevent build-up of scar tissue which would otherwise affect joint movement. Individuals who find themselves afflicted with these kinds of injuries can experience great emotional and psychological since an injury to our hands can threaten our

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independence and normality in a way few things can. This process is not only time-consuming and costly for the person injured; in the UK, over £100 million is spent every year treating these kinds of injuries (Dias & Garcia-Elias, 2006). Current rehabilitation is largely analogue, with no technological intervention, primarily due to cost. Data gloves, the most common technological rehabilitation aid, can potentially cost thousands of pounds (O'Donnell, 2010). There is a clear need for something accurate, portable and affordable.

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, these systems are most glove-based, with few alternatives. These glove-based systems are (for the most part) prohibitively expensive (O'Donnell, 2010) and the few alternatives such as Kinect (Bond, 2011) can suffer from portability and accuracy 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.

This paper outlines the design and development of a software based system for hand rehabilitation using the Leap Motion. The Leap Motion is a recently released motion-based device which has yet to be investigated as a tool for hand rehabilitation. User feedback comes primarily from an animated 3d hand model which will reflect the users hand movements in real-time. The results from the exercises are stored for later viewing by either the patient or a clinician. Furthermore, the project uses gamification elements to better encouraging patients to adhere to prescribed exercise programs.

2. HAND INJURIES

It is estimated that treatment for hand injuries costs the UK approximately £100 million per year. However, this problem spans much farther than the UK; the US for example, spends approximately $18 billion treating upper extremity disorders and Germany spends approximately €2 billion treating severe trauma with a ratio of 25 patients per 100,000 of the population (Dias & Garcia-Elias, 2006). Looking at RSI as a more specific example, we see that RSI alone is estimated to cost UK employers approximately £300 million per year (Strategy One, 2008). This is again mirrored in other parts of the world, with the US spending approximately $20 billion on RSI compensation each year (Yassi, 1997). Of all the hand injuries described above, amputation is deemed the most expensive, replantation of the hand or some part of the hand can cost up to 1.6 times a patient's annual salary. Nerve injuries are the second most expensive injury to treat, costing between €51,238 and €31,186 (Holmberg, et al., 1996). Speaking in more general terms, (Trybus, et al., 2006) calculate the mean cost of a hand injury to be $6126.76 or €4507.29. When discussing the financial impact of hand injuries, it is interesting to note the uneven distribution of direct to indirect cost. An example of a direct cost would be that of a surgical procedure whereas examples of indirect cost would include sick leave and outpatient travel. Direct cost was found to make up only 4% of the total expense whereas indirect costs made up the remaining 96% (Trybus, et al., 2006).

The impact of hand injuries is not just measured in terms of financial cost to employers through compensation or lost productivity; we can also use time related metrics such as work days lost or treatment duration in days when measuring the impact of injuries to the hand. Reports indicate that hand injuries account for 27% of all work-related injuries requiring more than 1 day of leave (G, 2003). Given that hand injuries are a world-wide concern, it is realistic to suggest that hand injuries can result in millions of work days being lost, as workers are forced to take leave in order to recover from their injuries. RSI for example costs UK employers approximately 3.5 million working

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