Scholar Report

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Title of Scholarship Project:	CAPTURING MOTION CAPTURE DATA FOR ANALYSIS OF MOVEMENT FOR STROKE PATIENTS WHILST PERFORMING ROBOTIC REHABILITATION

The Research

Over the six-week period in which the research project took place, I was tasked with developing a method for capture and analysis of motion data, which was to be used as a means of assessment for stroke patients undergoing robotic rehabilitation. This would entail research into multiple known methods. One method was the 'gold standard' of accurate motion capture, from which others could be validated and compared against. An added target was to not only develop and test ways of capturing position coordinates of motion but to assess and categorise the quality, smoothness and effectiveness of the motion.

My project began with a short literature review, in order to discover pre-existing research in the field of rehabilitation. Something I discovered early on in this exercise, was that much of this research was of a higher level than expected. This allowed me to focus my efforts on fewer, more concise goals, rather than a broad range of methods, for which I could only explore without much depth. Following the literature review, I began my first practical application of the knowledge I had gained, with the aforementioned 'gold standard' of accurate motion capture technology; NDI's 'Optotrak'. As stroke rehabilitation focuses heavily on developing and regaining the ability to live independently, my focus was on a fundamental part of daily life – drinking. Note that within the industry, such an activity is known as an ADL or activity of daily living, and henceforth ADL shall be used as a means of notation.

I needed to plan an experiment that would measure the coordinates of markers on a participant's arm whilst performing the ADL of drinking. All experiments require a thorough application process to the University of Leeds ethics board, and by extension, the NHS ethics committee for experiments involving patients as participants. Due to the youthful nature of my research, non-patient participants would be used, and hence a standard University of Leeds ethics application would suffice. Having studied psychology at A-Level, I was somewhat knowledgeable of research methods, the ethical implications of research and participant confidentiality. However, I had no experience in designing such things myself, merely criticising pre-existing work and suggesting areas for improvement. I decided to

spend some time reading previous applications made by some of the members of the department on similar research proposals in order to gain insight into some of the more focused precautions made when handling participant data. Some of these precautions included the destruction of data past a certain pre-arranged date, whilst others reminded participants periodically of their right to withdraw data from the research. It was brought to my attention that the usual time of approval for such applications can regularly exceed eight weeks, which initially I found slightly disappointing, as it would fall outside of my agreed research period, however, it soon became apparent that I could be more general in my application, for subsequent use when the research is continued by others.

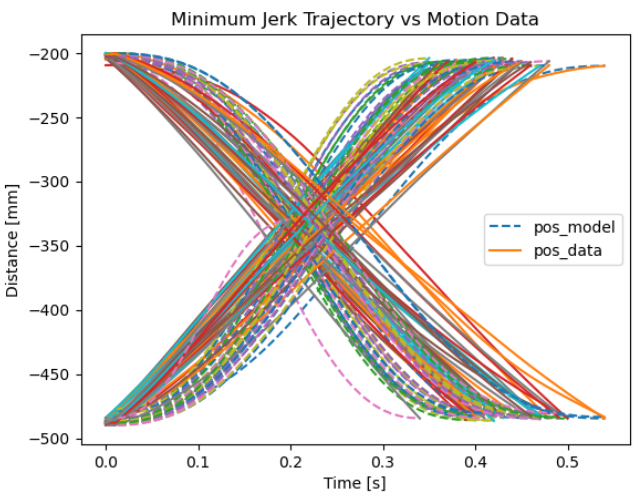
Another method of motion capture which could ultimately be compared to the 'Optotrak' system was Microsoft's 'Azure Kinect DK'. This system was initially promising, however, it proved to be a major curveball in the research flow. The system was to be used as a method of not only capturing the position data of an individual but also mapping their real-time motion onto a virtual avatar using the game engine 'Unity'. The set-up of the device took far longer than anticipated due to a general lack of online guides tailored to those new to systems such as these. Following the setup, it became apparent that the hardware we used to run the device was inadequate in terms of processing power and graphical capabilities. This resulted in a minor setback for the research itself, but a large blow to the practicality of the Azure system for home-based rehabilitation methods, as it would require the user to have an incredibly powerful (and by process of deduction, expensive) computer. The lack of lower-level guides, the demand for expensive hardware and the expertise needed for setup soon halted progress with the 'Azure Kinect DK', which despite having great application for a broad range of fields, wasn't something I could continue with given my timeframe to obtain useful results and feedback.

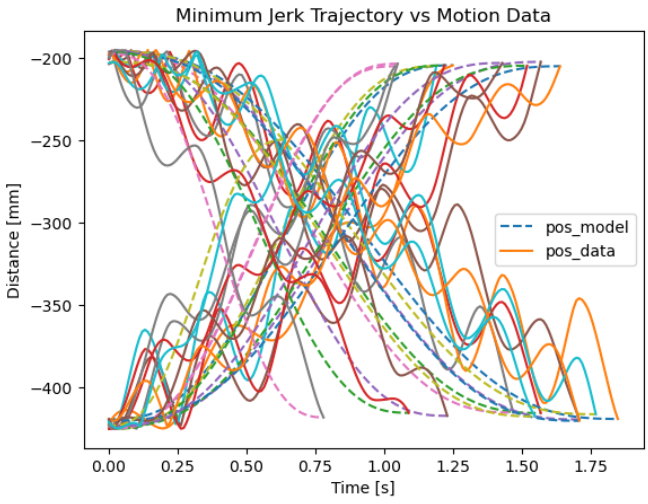
The remainder of my time researching was spent developing statistical analysis of data collected using the 'Optotrak' system. This gave me an opportunity to build upon my Python programming skills and my general knowledge of statistics. The main comparison I chose to adapt was a mathematical function describing the safest, smoothest and least damaging way of traversing from point 'A' to point 'B', known as 'minimum jerk trajectory' or MJT as it will hence be denoted by. MJT has been used as a function of interest for automated warehouse operations, for which packages containing a variety of items must be transported effectively, without any damage. Comparing human motion data to the mathematically perfect motion would have to be taken slightly loosely, as perfect motion isn't the goal of rehabilitation.

The basic data collection method used to test the motion quality program is depicted below. A single participant was fitted with markers (tracked by the Optotrak sensor) and was instructed to extend their right arm forward, and then retract it. This process was repeated for a minute, collecting 6,000 data points for each marker (of which there were four). Markers were positioned in such a way to collect coordinate data for the wrist and elbow, but given the small range of motion for the shoulder, shoulder position could be calculated too.

A B

Following some purposefully smooth and jerky data collection runs from both me and Dr Gallagher, I found the acceptably smooth motion to be of less than 25% error compared to the MJT, with jerky motion tending to exceed 30% error. It is worth noting that the method of data collection did not involve a 'switch' to signal a complete cycle when undertaking repetitive motion, so I had to sieve through upwards of 20,000 data points to assess extreme limits when it comes to where exactly 'A' and 'B' lie. Below are two datasets from the smooth (left) and jerky (right) motion of a single participant plotted against their respective MJTs.





There is a qualitative difference one can clearly see before examining the statistical differences in the dataset. The smooth motion follows a rough 'x' pattern with a minimal quantity of lines falling outside of the main structure, with an error of approximately 22%. The jerky motion, however, has no real discernible shape and this is supported by an error of around 44%. Following further trials with multiple participants, if it is found that a vast majority of datasets follow the above pattern, the research can move forward using AI to determine smooth and jerky motion given these predetermined boundary conditions.

Overall, I am pleased with the outcomes of my time in the lab, as it can be further developed and tweaked over time for real-world application. My research was very much a 'proof of concept' exercise to assess whether any of these methods, hardware or software, are worth developing further. Having found categories denoting smooth vs. jerky motion, assessing the practicality of different motion capture techniques and laying a foundation for further study with a fully complete ethics application, one could deem the endeavour a success.

Future Impact

The research I conducted will hopefully create a foundation for individuals in the future to build upon and develop further, with home rehabilitation for stroke patients being the overarching goal. The method I developed for dividing repetitive motion into monodirectional segments (lifting the forearm is distinguishable from raising the shoulder) will be fine-tuned using switches or sensors to indicate when a single cycle of motion has been completed, which would in turn, reduce the requirement for any human input as far as data analysis is concerned. The plans for the future of the project are to develop a machine learning algorithm, that learns a multitude of indicators, scenarios and criteria to categorise quality of motion, which could then be implemented into interactive and engaging games for home use. These games will encourage movements and actions associated with independent living in a less direct manner than that seen in rehabilitation wards. Thus, adding a level of reward for players (in this case patients) in the form of various virtual attainments, such as a high score, the ability to change one's avatar appearance or even the unlock of new, more complex games to further develop recovering motor function.

In order to spread knowledge and understanding of the research, I completed weekly research logs, posting them to the Laidlaw Scholars Network, and I intend to publish a research paper discussing my findings in further scientific detail at the Leeds Student Education Conference.

The effect research has had on me as an individual and a leader

Conducting research over the summer has greatly added to my skillset, as well as sharpened my pre-existing skills. I further developed my coding capabilities previously learnt during the first year of my degree, which not only puts me a step ahead when preparing for further studies in computing during my degree but has also given me the ability to find practical applications from theory learnt. The ability to think practically is a key part of being an employable physicist, and so the opportunity to conduct this research has greatly assisted me in developing the asset. Furthermore, before being accepted into the Laidlaw Research and Leadership Programme 2023 Cohort, I voiced a desire to better adapt to adverse situations, especially in an academic environment. I hoped things would go wrong, an inevitable part of research, such that I would have to overcome impasses, something I'm

grateful to have accomplished in my research. The Azure Kinect DK provided a great learning opportunity, as whilst the system setup didn't go to plan, it became apparent that my failure to do so itself was a valuable takeaway both for myself and for the future of the research project and those who continue with it. The ability to handle defeat or a complex situation presented in adversity is a valuable trait for leadership, as despite my experience being in solitary research, it can be easily applied to a team. If something doesn't go to plan, it is a leader's responsibility to make their team aware of the situation, but to keep the morale high, the accusations low and the unit together. Resource management is another skill crucial to leadership, not only to run an effective operation but to also prevent the overworking of some individuals and the possible side-lining of others. I learned to effectively manage my time and resources over the six-week research period. Due to security reasons, I did not have ready access to the rehabilitation lab in which I was primarily based, and so when granted access in some cases as little as a day a week, I had to make sure my time spent in the lab was useful and effective. I am grateful to have been burdened with such at an early stage in my life, as I will be prepared for when it occurs again, be it a budget cut, a staff cut or reduced time allocation.

Future Career Aspirations

I am about to enter my second year studying an integrated master's course in physics at the University of Leeds. I have a keen interest in medical applications of physics, particularly in nuclear medicine and diagnostic radiology. Hence, I have opted to take medical-based optional modules in order to cement some knowledge for the future. I intend to apply for the NHS scientist training program, to become a registered clinical scientist, specialising in medical physics. This will either be done immediately after graduation or following the pursuit of a doctoral qualification in a relevant field. The reasoning behind such aspirations is my desire to provide a helpful, real-world application to the knowledge I acquire and to see the effect ground-breaking research can have on individuals.

Supervisor

Please comment on your scholar's research period, what you consider to be your scholar's strengths and which leadership attributes you feel your scholar has demonstrated and is particularly skilled in. You could also identify areas in which your scholar can develop further.

Arron did a 6-week placement internship at our Rehab Lab in the Bragg and Mechanical Engineering buildings. It is a short time to do a research project and get results, but Arron did very well. He was able to stick to a tight plan and work diligently. He gathered background information up front which could be used throughout the placement. An understanding of research ethics was gained early on in the project. Arron was then able to design an experiment in which he would collect human arm movement data. The method of data collection was explored through motion tracking systems and cameras. He was able to get data and create his own analysis functions.

There were times when Arron struggled with some technical aspects, being thrown in the deep end. But he persevered and was able to gain a lot of knowledge in a short time. I'm sure he learned a lot in the process, and we gained valuable information for future research.

Arron used his leadership skills to manage himself and the project very well. He was able to present and disseminate his findings orally and in written form (in this paper).

It has been a pleasure working with Arron over the summer. I would like to wish him all the best for the future and hope he can keep in touch.

Signature of Scholar: Arron J Thompson Date: 02/10/2023

Signature of Project Leader: Dr JF Gallagher Date: 01/10/2023