Oom Bop Bop Good Vibrations: the use of sensory feedback to create motion inhibition

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Oom bop bop good vibrations: the use of sensory feedback to create motion inhibition

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Abstract

The use of suits that restrict or inhibit joint motion have been used to aid the design of various kinds of products from cars to wheelchairs and kitchen equipment. Their principal aim has been to allow designers and engineers to understand what it is like to use these products as an older person might use them, effectively prematurely ageing the user.

Such suits have been highly successful but suffer several limitations in their use. In using mechanical stiffeners on the joints such as the stiffening effect of the suits depends on the strength of the user; weaker users will find their range of motion reduced more than stronger users. This also raises the question of the sensitivity of such suits; in reality motion restriction may be linked to pain and discomfort hence motion restriction is likely to be more psychological and musko-skeletal than current suits provide.

Work has been ongoing at SHU to develop a suit that restricts motion by providing sensory feedback to the user. Specialist software was developed which set motion limits to goniometers which in turn would make motors vibrate if those limits were reached. This work outlines the development of this suit and initial applications for which it has been used.

Keywords: 3rd age suit, motion capture, goniomoter

Introduction

Society is ageing and that ageing brings with it a host of issues not least a society in which the majority may have some form of disability such as arthritis, sensory loss and mobility issues. Within the design community there has been the development of design techniques and methodologies towards an understanding of the wants and needs of older people with regards the development of products and services that better meet the requirements of this ageing society.

The development of inclusive design techniques whereby designing these products and services that are not only equitable in use but meet the needs of society as a whole has been ongoing for a numbers of years [1, 2]. One of those techniques has been the development of what has been termed third age suits. In theory these suits replicate the issue of ageing (loss of strength, dexterity, locomotion, hearing and vision) and can be worn by designers and engineers to understand these issue first hand during the development phase of the design process.

Three examples of the third age suits are shown in Figure 1 below. Generally these suits use straps and padding on the arms, legs and hands to limit joint movement and ear defenders and yellowed goggles to simulate hearing and vision impairment.

Figure 1: three types of third age suits

The suits were first developed for use in the automotive industry but since then have been used widely in the design of assistive technology, working environments and fast moving consumer goods [3-5].

Work within the Lab4living (a collaboration between the Art and Design Research Centre and the Faculty of Health and Wellbeing) at Sheffield Hallam University has been ongoing looking at the design issues around the development of assistive technology, bathrooms, packaging, household cleaning equipment and recycling activities to name just a few. The Lab4living utilises a number of design techniques from surveys, focus groups, co-creation techniques, peer researchers, to motion capture, thin-film force sensors and numerical and analytical analyses. These techniques allow for understanding both the physical and psychological elements of artefact use.

Through undertaking these studies it was recognised that there was a need for some kind of third age suit to aid in the understanding the physical limitations (or otherwise) of the products and services that the lab was developing. To that end the authors undertook a study to establish the state of the art with suits of this kind and options as to whether to purchase, hire or design a suit themselves.

After studying costs, flexibility and limitations of other suits the Lab4living team decided to build a suit for themselves. A key element of this decision was to study if the suit could give feedback to the user to control the motion rather than rely on mechanical means as with current systems. The disadvantage of mechanical systems is that they can be heavy and give a different 'feel' for each user. For example a young healthy male will be able to exert a different range of motions than a middle aged female. A suit that enables user feedback should in theory be able to limit the users' range of motions exactly from one user to another.

Hence in testing this theory and developing a prototype suit several key areas had to be studied. These were:

- choice of feedback systems and sensor location
- attachment system and suit design
- calibration and testing

Methodology

Feedback System and Sensor Location

In order to develop a suit that would essentially give sensory feedback to the user three feedback options were proposed; audible, electrical and vibratory. Audible feedback was quickly discarded since this would require the users to remember which sounds related to which muscle movement. Electrical stimuli to the muscles were also tested. This had the major advantage of actually being able to override the body's own electrical impulses to the muscles and hence enable the muscles to 'lock' when angle limits were reached. However in testing this system the authors found that in certain instances the electrical impulses were uncomfortable. Hence a vibratory system was settled upon. The system was designed to drive small electric motors that would pass vibratory signals to the muscles when excited.

Twenty subjects (12 female, 8 male) had the motors held against differing muscle groups. The motors were set at a low voltage and moved over the muscle surface to test sensitivity to location. The test was repeated for all subjects both directly to the skin and through clothing. It was found that even on the lowest settings the batteries were able to provide sufficient power to be felt by the users through clothing such as jeans. Further users were seen to be insensitive to the exact positioning of the motor on the muscle to be able to sense the vibration on that muscle. One of the motors is shown in Figure 2 below.

Figure 2: Motor testing for location and sensitivity.

Attachment Systems and Suit Design

The theory behind this suit as explained is to control the movements of the user using vibrational feedback. It was important that the suit allowed flexibility for the user and was light and allowed for free movement. Hence a wireless system was proposed whereby the system was driven by software remotely from a pc and wireless controller.

Each motor and goniometer system needs to be powered and it was decided to have a central 'power-pack' that powered each motor and goniometer. The advantage was seen that motor attachment would be simpler and lighter on each muscle group and the 'powerpack' could be located at the waist again reducing the effect on the user.

This was in effect a trial of the technology and to that end the authors only had limited resources. Hence we selected to build a suit that concentrated on nine muscle systems. These were two on the shoulder (to measure both vertical and horizontal motions), one on the elbow, one on the back on the spine and one on the side. Two further sensors were to be placed on the knee and ankle. The positioning is shown schematically in Figure 3.

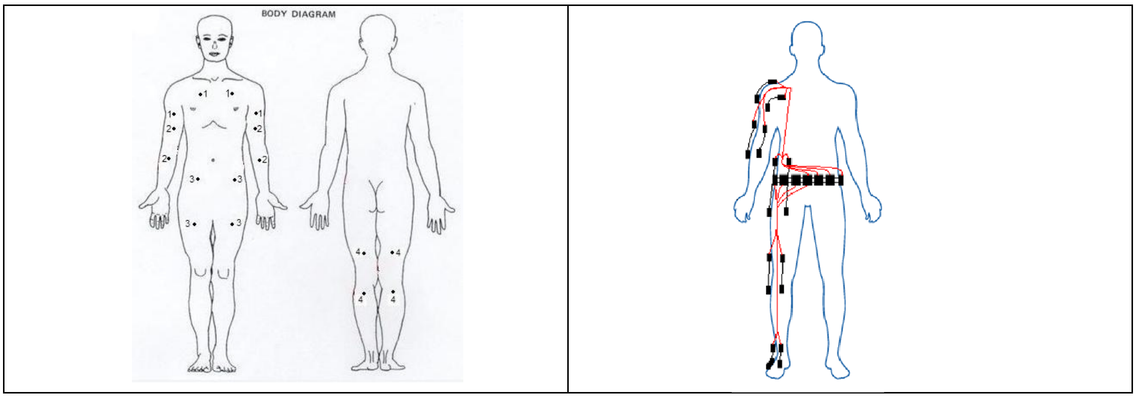

Figure 3: schematic diagram for sensor location

Specialist software was designed to drive the sensors remotely from a PC and to set the levels at which the motors would vibrate. This is shown in Figure 4.

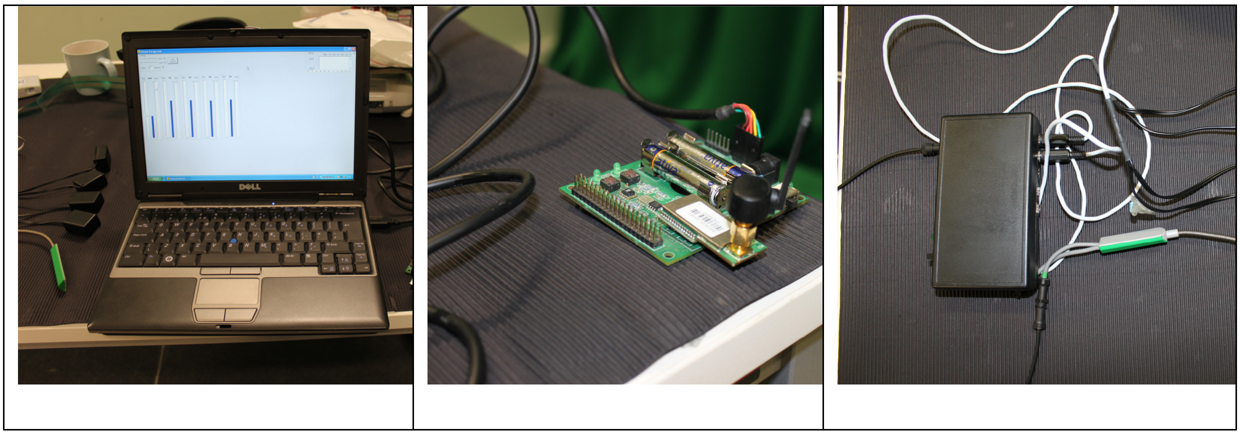

Figure 4: Sensing software, wireless receiver and goniometer motor systems.

Various methods were determined as to how the wires and motors should be attached to the body. Pockets, clothing and straps were considered and the system chosen for the initial testing was a combination of tight clothing along with pouches this is shown in Figure 5. For testing purposes the suit concentrated on the shoulder and elbow.

Figure 6: Initial testing suit.

Calibration and Testing

The authors used an 8 camera MAC-Hawk motion capture system to calibrate the goniometers. The motion capture system works by triangulating the positions of reflective markers using infra-red cameras once such camera is shown in Figure 6. By placing markers on the ends of the goniometers we could track the movements of the system assess the linearity of the goniometers and calibrate our software interface.

Figure 5: Hawk motion capture camera

In calibrating the gonimoters the initial test involved laying a goniometer down on a flat surface, then passing the goniometer all the way through 180 degrees so that both ends of the goniometer met. Recording what the third age software had measured and then a comparison with the motion capture could be made. The angle calculated using motion capture was 180 degrees. This meant that each section on software represented 10 degrees. The test and the software screen can be seen on is shown in Figure 7.

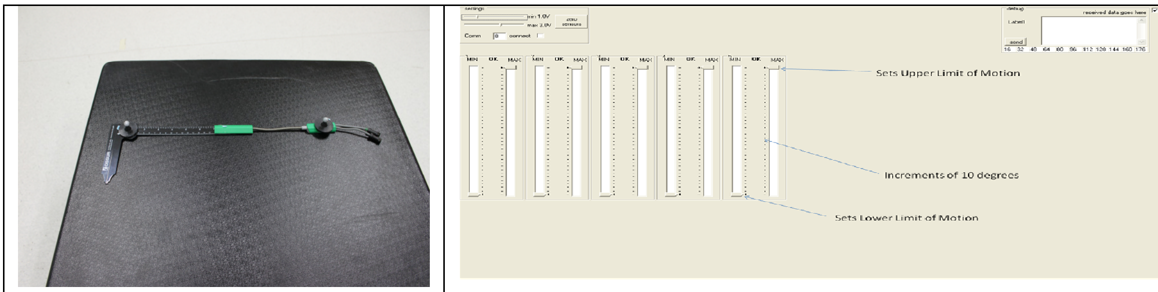

Figure 7: Gonimoter test and software screen

Fifteen subjects (8 male and 7 female) participated in this experiment after being informed about the aim and clinical implication of the experiment. The mean age of the participants was 34 (range 25 –60 years). All were in good health and free of any lesion or impairment in the upper limbs. At the beginning of the experiment, each subject was provided with an informed consent form and a brief description of the goals and procedures of the experiment.

Several tests were undertaken on the suit to establish the ease of use and effectiveness of the control system. The tasks were based around cleaning activities such as mopping, hoovering and vacuum cleaning.

Results

Participants undertaking the tests are shown on Figure 8 below. In these tests only three gonimoters were used, to test the system (although the system and suit were designed to accommodate more). The goniometers used were the for the elbow, shoulder lateral and shoulder anterior (frontal).

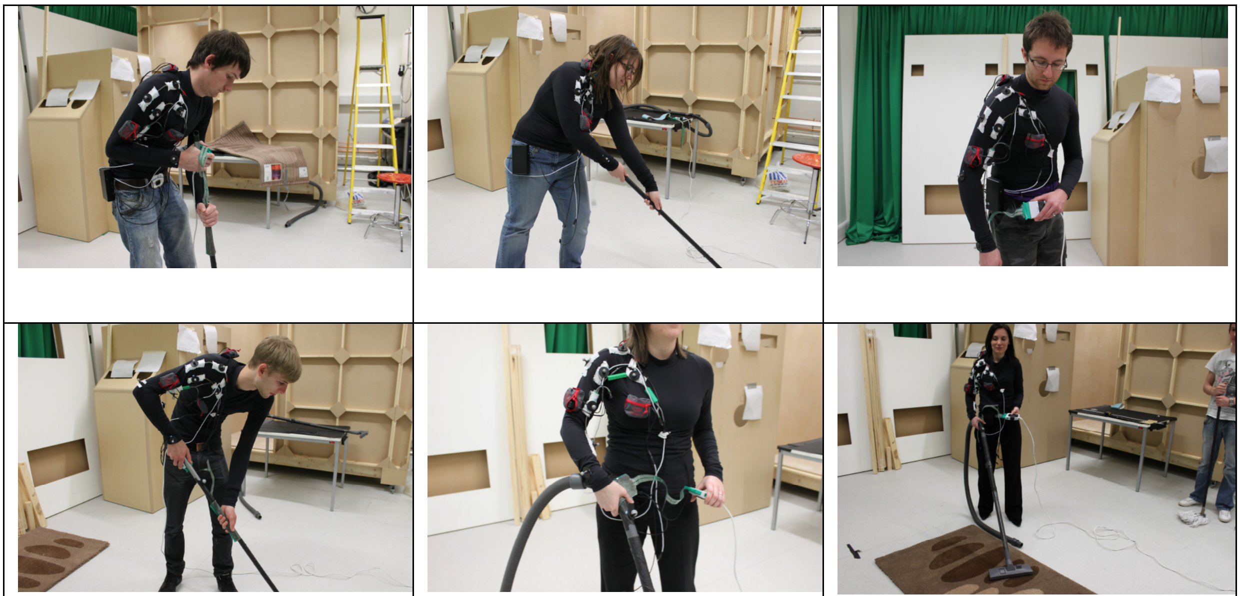

Figure 8: Participants mopping and vacuum cleaning wearing the initial suit.

Ths suit was used in conjunction with a motion capture system. The motion capture calibration set-up and schematic of the virtual system is shown in Figure 9. Figure 10 shows the marker set-up on the person and vacuum in detail.

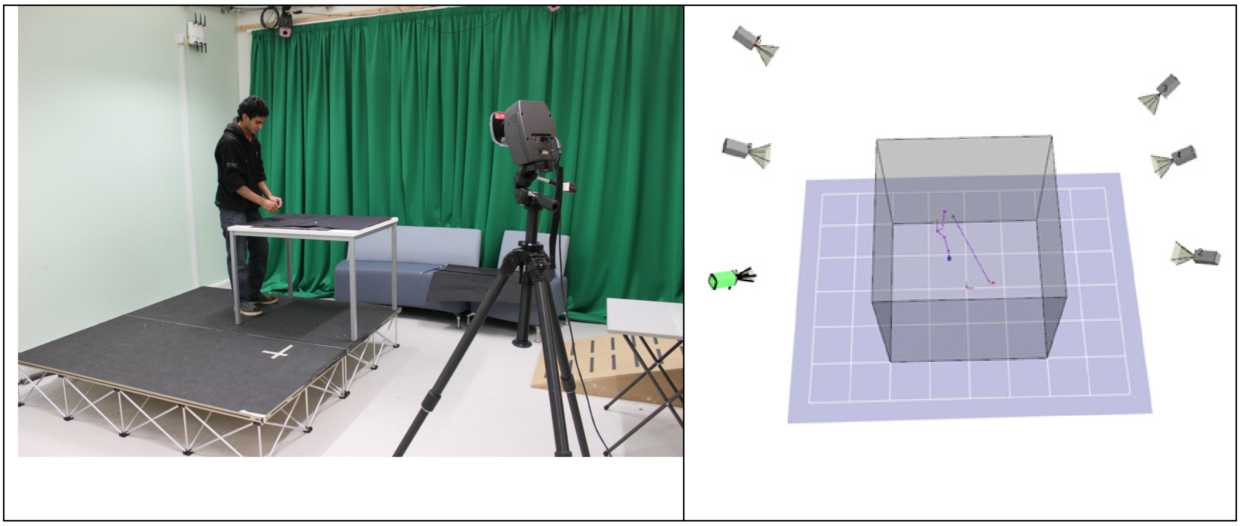

Figure 9: Motion capture calibration and virtual system set-up

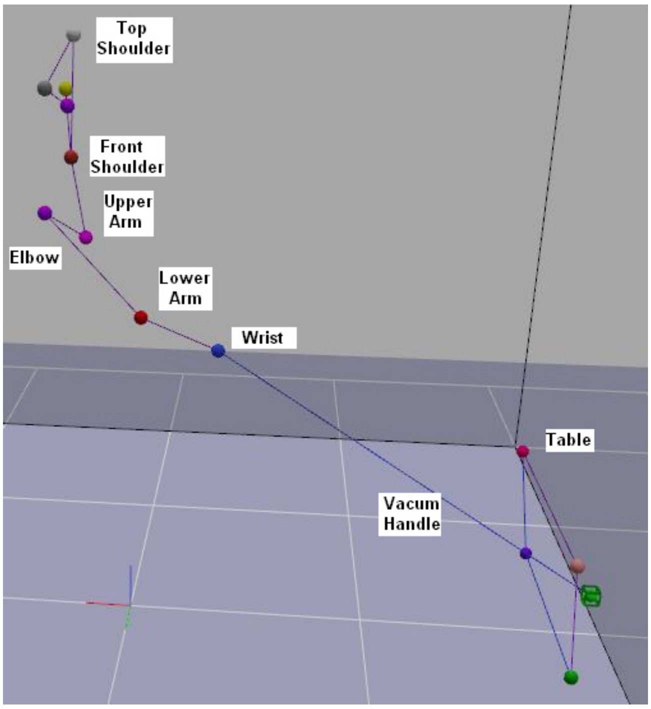

Figure 10: Virtual marker system

Several tests were undertaken, participants were allowed to mop and vacuum without vibration to study the typical angles that their limbs underwent during the mopping a vacuuming process. Angles were calculated as shown in the Figure below:

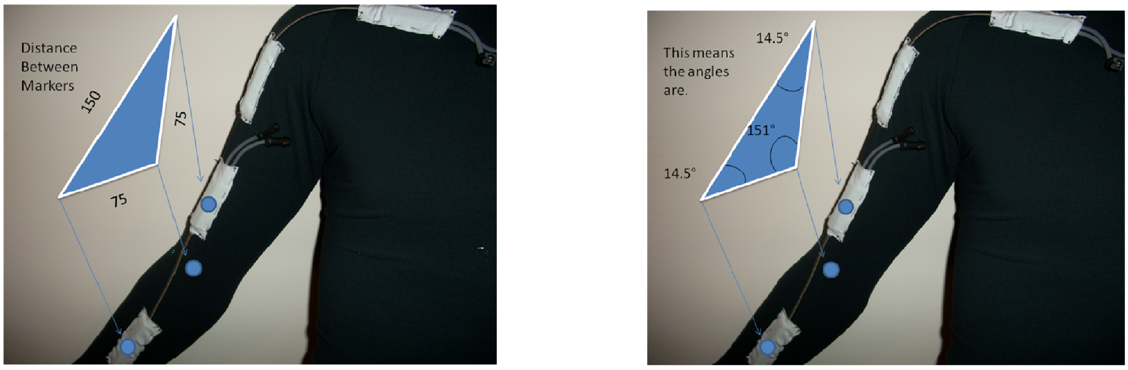

Figure 11: Angle calculation

Once typical angles were established the angles were set at which the motors would start to vibrate. The aim was to see if by controlling a typical angle from one user we could then 'map' or control that behaviour onto other users. From the initial tests an elbow angle in the vertical plane (shown as 151° in Figure 10) was limited to 90°, i.e. the user would be unable to pull their arm backwards with an elbow angel less than 90°.

Tests were undertaken on the fifteen subjects and it was found that the system was able to limit the users elbow angle to within 1°. Tables of average results are shown in Tables 1 and 2 below. Further questions were asked each user and are discussed in the section below.

Table 1: Average Distance data and Angles for Vacuum Cleaning

With Vibration					
Distance (mm)			**Angle (^{0})**		
AB	**AC**	**BC**	**A**	**B**	**C**
203.7	130.6	242	90	57	33
248.1	87.1	262.9	89	71	20

Table 2: Average Distance data and Angles for Mopping

With Vibration					
Distance (mm)			**Angle (^{0})**		
AB	**AC**	**BC**	**A**	**B**	**C**
119.9	206.6	238.9	90	59	31
207.46	256.6	330	90	51	39

Discussion

A questionnaire was presented to all of the participants undertaking the test. The questions as part of the test were as follows:

1. Do you feel comfortable wearing the suit?
2. Do you feel the suit is too tight?
3. Does the suit restrict your movement in any way?
4. Do you feel the suit works in the way that I explained?
5. Are there any parts you feel did not work?
6. Are there any parts you would change?
7. Do you feel the suit reacts in enough time?
8. Do you feel the suit gives you sufficient warning?
9. Do you feel the suit makes you want to stop?

The largest issue with the suit was that 20% of participants did not feel comfortable in the suit and that 30% felt that the suit was too tight. This was particularly true of the female participants who when questioned felt very self conscious in the suit and that it was difficult to get into and was quite revealing once on.

All participants felt that the suit worked as explained gave enough time and did indeed make them want to stop.

Further testing of the suit recorded hand grip and force data (during suit use) and is the subject of further research. Of interest however that significant difference is in hand grip force data was recorded during the mopping and vacuum cleaning process was shown between genders when using the suit and not.

Figure 12 shows the force time data for men and when using the suit and not. This data was recorded using Tekscan thin-film force sensors placed on the mop and vacuum cleaner handle. These sensors can be seen on the handle in Figure 7.

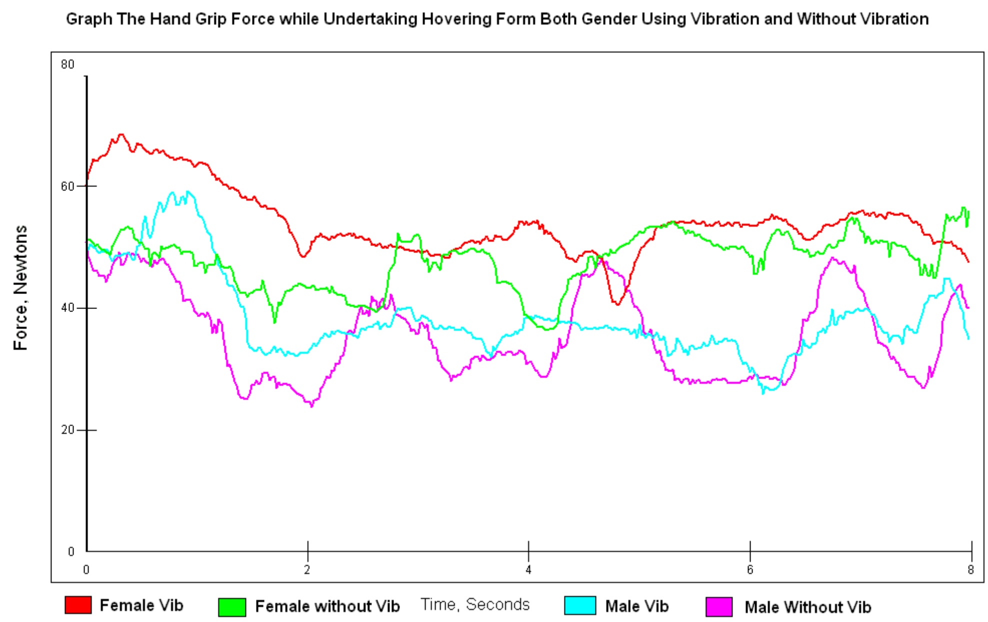

Figure 12: Graph hand grip force while undertaking hoovering from both genders

Conclusions

The initial purpose of this research was to examine if a 3rd age suit could be designed that was able to limit joint motion in a user and be able to map that motion onto other users. Simple tests showed that this was indeed possible and further work is underway testing multiple joints (i.e. the elbow and the shoulder in conjunction) and hip and knee joints.

Of interest is that women were seen to behave differently in the suit in that they felt very self conscious in both wearing and putting on the suit but it seems that wearing the suit created a bigger variation from their 'normal' hand grip force than not.

This leads to the hypotheses that female users were more self conscious when using the suit and that whilst the suit was able to control motion it did have a subtle effect on other measurements. Further work is ongoing to test this hypotheses including making the suit easier to put on and to hide the suit under a more 'baggy' outer layer. This should be fairly simple now the suit and software are calibrated and the suit can be used separately from the motion capture system.

Further software refinement is also ongoing in particular the ability to store individual user goniometer limits.

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