Designing a new model for the elderly in an assisted

ITERATIVE PROGRAMMING OF THE NAO ROBOT WITHIN A MULTIDISCIPLINARY DESIGN ENVIRONMENT.

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Designing a new model for the elderly in an assisted living facility

Iterative programming of the NAO robot within a multidisciplinary design environment.

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To my parents, who have always supported me, and to my new family, that I have met here in Sweden...

Thanks!
Abstract

It is estimated that, by 2050, the number of people aged 65 and above will have grown in the European Union by 70%, and people over 80 will have grown by 170%. Therefore, Health Care faces three major challenges: the population of Europe is ageing, Health Care is increasingly effective but also becoming more expensive, and patients, having become true consumers, are also more demanding. The project “PhySeEar” was born with the aim of improving the quality of physiotherapy sessions as well as turning them into a more engaging and lively therapy. This project was performed in the “Nuestra Señora de la Soledad” assisted living facility in Tocina (Sevilla), Spain. During this project, an event happened without being agreed on beforehand: the physiotherapist made the system act as “the bad cop”, while he became closer to the inpatients being himself “the good cop”. Therefore, the system became in charge of evaluating the inpatients, while the physiotherapist helped them “beat the system”. This finding motivated new research in this field. The purpose in the current project is to design, develop and evaluate a semi-autonomous system to assist physiotherapists in training situations. This involves aspects of the “good cop”/“bad cop” roles, reducing the physiotherapist’s workload through semi-automatic feedback and engaging the inpatients in the therapy. Three systems have been implemented with this intention. The first system uses the NAO robot to model the movements the inpatients have to mimic. The second one uses a virtual version of this robot for the same purpose. The third system uses the NAO robot to model the movements and Kinect to evaluate them. As a conclusion, a guideline based on the knowledge acquired during this thesis has been developed. This guideline consists of recommendations related to the design of a model that will perform certain movements, the use of the Kinect technology in order to track inpatients’ movements and how the system should interact with the physiotherapist during the therapy. This guideline should be considered for future works in this scenario.
Resumen

Está estimado que dentro de la Unión Europea en el año 2050, el número de personas mayores de 65 años crecerá en un 70%, y las personas mayores de 80 años lo harán en un 170%. Por tanto, la atención médica se enfrenta a tres grandes retos: la población de Europa está envejeciendo, la atención sanitaria es cada vez más eficaz, pero también cada vez más cara, y los pacientes, habiéndose convertido en clientes, también son más exigentes. El proyecto “PhySeEar” nació con el propósito de mejorar la calidad de las sesiones de fisioterapia así como de hacerlas más atractivas y amenas. Este proyecto fue desarrollado en la residencia para la tercera edad “Nuestra Señora de la Soledad”, Tocina (Sevilla), España. Durante su desarrollo ocurrió un evento no previsto bastante llamativo: el fisioterapeuta usó el sistema creado para que actuara en forma de “poli malo”, mientras que él se mantenía más cercano a los pacientes en el papel de “poli bueno”. De esta forma, el sistema estaba a cargo de evaluar a los pacientes, mientras que el fisioterapeuta los ayudaba a “ganar al sistema”. Esta nueva redistribución de los roles motivó una nueva investigación en este campo.

El propósito de este nuevo proyecto es el diseño, desarrollo y evaluación de un sistema semi-autónomo para ayudar al fisioterapeuta durante las sesiones de rehabilitación con ancianos. Este objetivo también engloba aspectos tales como mantener la nueva distribución de roles (poli bueno, poli malo), reducir la carga de trabajo del fisioterapeuta y animar a los residentes a participar en las terapias voluntarias. Con esta intención, tres sistemas son desarrollados. El primer sistema utiliza el robot NAO fabricado por Aldo debaran como modelo para representar los movimientos que posteriormente los ancianos deberán imitar. El segundo utiliza como modelo una versión virtual del mismo robot. Y el tercer sistema añade el dispositivo Kinect fabricado por Microsoft al entorno de trabajo. Este dispositivo contribuirá en la evaluación de los pacientes mientras que el robot NAO seguirá siendo el modelo para representar los movimientos. Como conclusión se desarrollan unas directrices en base a los conocimientos adquiridos durante esta tesis. Estas directrices están formadas por recomendaciones a la hora de diseñar un modelo que modelizará ciertos movimientos, el uso de Kinect para analizar los movimientos de los pacientes, y cómo el sistema debería interactuar con el fisioterapeuta durante el transcurso de la terapia, por tanto, estas directrices debieran ser consideradas para futuros trabajos relacionados con este escenario.

Como conclusión se desarrollan unas directrices a seguir para futuros proyectos en base a los conocimientos adquiridos durante esta tesis.
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I would also like to include some special remarks for all my friends:

- “We are what we repeatedly do. Excellence, then, is not an act, but a habit” - Aristotle. Do not ever get tired of your habit Alberto Fernández.
- “I’m with the party rock crew” - LMFAO. You are part of this crew Jesús Paredes
- “A single rose can be my garden...a single friend, my world” - Leo Buscaglia. Never stop being part of my world Cecilia Rodríguez
- “Sometimes the heart sees what is invisible to the eye” - H. Jackson Brown, Jr. Thanks for supporting me from afar Pilar Isla.

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List of Acronyms

HCI  Human-Computer Interaction
DC   Direct Current
CMOS Complementary Metal-Oxide Semiconductor
LED  Light Emitting Diode
Wi-Fi Wireless Fidelity
SDK  Software Development Kit
PhyNAO Physical NAO
ViNAO Virtual NAO
RGB  Red-Green-Blue
VGA  Video Graphics Adapter
IR   Interference Rejection
Chapter 1

Introduction

By 2050, the number of people aged 65 and above is estimated to have grown by 70% and people over 80 by 170% in the European Union [26]. Therefore, Health Care confronts three major challenges [1]:

- The population of Europe is ageing.
- Health care is increasingly effective, but also becoming more expensive.
- Patients, having become true consumers, are also more demanding.

In order to improve the quality of physiotherapy sessions and turn these sessions into a more engaging and lively therapy, several projects have been developed [65] [2] [24], highlighting the importance of motivation in the elderly as a major issue [2] to avoid boredom and keep them engaged in therapy. PhySeEar [44] was born in a similar scenario where an improvement in the quality of the therapy was aimed at (see Section 1.1), trying at the same time to motivate the inpatients (patients who live in an assisted living facility) to attend rehabilitation therapy. This research will represent the basis for this master thesis project and is described in the next section.

1.1. The PhySeEar project

The PhySeEar project [44] was performed in the “Nuestra Señora de la Soledad” assisted living facility in Tocina (Seville), Spain. The motivation problem in [44] was highlighted by the centre’s physiotherapist. The elderly people’s motivation to take part in the rehabilitation relies mainly on the emotional bond they have with the physiotherapist. This has some advantages, but also some disadvantages, since the inpatients also use that emotional bond to do illicit “emotional blackmailing” and to try to do less movement repetitions than required. Hence, a group composed of an interaction designer/engineer, the physiotherapist of the centre, and a psychologist, devised and tested two systems that would make rehabilitation more amusing and efficient.

In [44], the inpatients had to exercise as usual during the rehabilitation intervention with the physiotherapist. Essentially, they exercise by making certain movements as moving their arm/leg forward/backward or lifting and bending their knee. To evaluate these movements and give the inpatients feedback, they used Wizard of Oz methods [51]. These methods were selected in order to explore the design space of computer-assisted physiotherapy training. In that phase, the simulated system focused on placing feedback on the participant’s own body. Chiefly, they made an observation. When the physiotherapist needs to evaluate and correct the inpatients’ performing of movements, the inpatients sometimes do not think their performing is wrong; instead, they complain to the physiotherapist for correcting them. Since the researchers introduced a piece of technology into the therapy that provided the old people with a movement evaluation tool, they relieved the physiotherapist from the negative emotional consequences that assessing and correcting the inpatients implied. In addition, without being agreed on beforehand, the physiotherapist made the system act as “the bad cop”, thus becoming himself closer to the inpatients and assuming the role of “the good cop”, trying to explain them how to “beat the system.”
This division of roles between the physiotherapist as the “good cop” and the system as “bad cop” was the key design element in the new phase of the project. Essentially, the new target became to emphasise this duality of roles through a more anthropomorphic system design.

![Previous work in [44]](image)

**Figure 1.1: Previous work in [44]**

### 1.2. Goals and problem description

The goals of this thesis are to design, develop and evaluate a semi autonomous system to assist physiotherapists in training situations. These goals involve:

- Developing a system that supports the physiotherapist in performing a “good cop” role.
- Reducing the workload currently on the physiotherapist through semi automatic feedback. Their amount of work is too high. For instance, as our physiotherapist points out, he barely has time to write all the inpatients’ reports in a proper way. With this project we expect to release him from some of his functions or at least help him while he is doing them.
- Stimulating the inpatients’ experience and engagement - basically, by making the whole sessions more amusing while maintaining the training goals.

### 1.3. Research questions

As a result of the different approaches that might fulfill the aims described above, this project is split into two iterations. In each iteration, a group of key research questions is proposed according to the system that will be designed in that iteration. Thus, the questions are presented within the iteration they belong to:

- **Iteration 1:** Feedback from a semi autonomous physical and tangible three-dimensional model versus feedback from a semi autonomous virtual screen-based model. The physiotherapist will control the output of both systems.
  - Question 1: Test two different semi autonomous models and detect differences if they exist. The models will be:
    - Robot NAO from Aldebaran [45].
    - A virtual version of the same robot.
  - Question 2: What does a semi autonomous model add to the physiotherapist’s interventions?
1.4. **Contribution of this research**

Thanks to the knowledge acquired during this project, we are able to design systems to be used in physiotherapy with the elderly, and write down a guideline to be followed during the implementation process of such systems. This knowledge is obtained from understanding and integrating several major issues related to the therapy with the elderly. Particularly, it is necessary to witness how the physiotherapist behaves in front of the old people, how they behave within the intervention and the roles that each one (physiotherapist and inpatient) perform during the session. As a result of this learning process, three systems are developed, together with a set of guidelines.

The main objective of these systems is to model the movements that the physiotherapist must do during the rehabilitation interventions. Moreover, an evaluation function is included in the second iteration, providing the system with a larger grade of autonomy. As a result of this addition, the systems may be divided into two groups:

- From a semi autonomous perspective, two systems are developed. These systems provide the same feedback, but with distinct properties. The first system uses videos to model the movements, and a robot is used in the second system.
- From an autonomous perspective, Kinect is added to a system which keeps the robot as the movement model.

In the guidelines section, the knowledge obtained from how physiotherapist and inpatients behave is included. Moreover, it includes instructions and suggestions for a reliable working system and possible risks that must be considered.

1.5. **Limitations**

In this section, the limitations of this project are described. Initially, a brief description of the implemented movements is presented. Next, the robot’s movement constraints, Kinect’s using conditions and the reason why are these technologies were selected to model and evaluate the movements are explained. Finally, some technical problems are introduced.

During the development of this project, it is especially important to highlight that the physiotherapist cannot be physically contacted and his availability is quite reduced. In addition, the physiotherapist works in Spain. Therefore, all feedback from the physiotherapist is received via email.

The first approach to the design of movements comes from a set of pre-established movements proposed by the physiotherapist (Appendix A). Hence, the designer can only work with this set of movements.

When the movements specification is received via email, the representation of those movements must be adequate to our robot’s capabilities. In essence, that means that the movements representation is constricted by the robot’s physical restrictions. At the same time, as the virtual representation of the robot has the same physical characteristics as the robot itself, it suffers the same limitations.

Finally, once the movements are designed and implemented, they must be approved by the physiotherapist to be used later on. Both the approval and the movement refining process are done by video analysis because of the physical limitation caused by the physiotherapist’s current location (Spain).

Besides, to be able to properly use Kinect, the inpatient must be allocated no farther than four meters from it [36]. Although this is in fact a limitation, it is not a major problem because during the usual physiotherapy sessions the inpatients are usually around one meter from the doctor.
1.6. METHODOLOGY

Facing the question about why a robot is chosen to model the movements, it is a matter of fact that other devices could be used as a tangible interface [24] or a virtual agent [15]. However, since there is an apparent need for the physiotherapist of a “model” that performs the movements; to use a physical three-dimensional model, which is closest to what the physiotherapist does, becomes a design requirement. Thus, the NAO robot [3] could act as the required model. In order to create an autonomous system, we could have used different technologies to capture the user’s movements, like wearable sensors as in [50]. However, one of the requirements is to make the system as unobtrusive as possible. This fact suggests the use of technology for tracking the movements from afar, like Kinect.

Finally, there were some problems with NAO’s C++ libraries installation. Alternatively, the laptop uses C# and .Net to control the robot. This limitation will affect Kinect’s code development as all this code should be written using C#.

1.6. Methodology

In this project, an iterative and incremental development model is followed [34]. This process encompasses two main iterations where different systems are developed. These systems profit from the experience obtained from previous works on the subject, in order to prevent falling into the same mistakes. Therefore, in the first iteration, the requirements established by the physiotherapist fix the initial point that will be submitted to analysis. Based on the requirements and the analysis phases, in each iteration, the design is turned into a system by implementation. Finally, this system is tested and the results will be part of the requirements for the next iteration. To be more specific, in the following lines, the iterations details’ are further explained:

1. Iteration 1: the physiotherapist is in control of the system, as in the PhySeEar project [44]. He is “the game master” in “play”, just like in [44]. In addition, the system models the movements that the inpatients should mimic.

2. Iteration 2: the system is autonomous in “judging” and providing feedback on the movements, setting the physiotherapist free from this task, and encouraging to take a more didactic or pedagogic role. He is expected to be more focused on the body of the inpatients and to explain the correct execution of the movements.

It is important to emphasize the adoption of technology as design material as in [55] [27]. Our methodology adopts the “experimental artifacts” idea [56], where according to Sundström: “Experimental artifacts are carefully implemented systems that allow for a very precise experience, each shaped by the affordances of identified digital material. Even though such artifacts do offer experiences, these serve no purpose or goal and are not meant to be final systems. What matters, is that they work, they are implemented and provide an experience that is there for a design team to explore”. With this in mind, we use the concept of simple experimental artifacts, being ours more complex. To illustrate this better, in [56] they explore Bluetooth. In essence, they conclude that it is valid to use a device (Bluetooth) out of its traditional functionality (data transmission) if it can be used for other purpose in a reliable way (detecting other devices’ positions). Similar to what Sundström does in [55], a piece of technology is chosen and incorporated to the system in order to explore which possibilities it could add to the system. We incorporate a new technology to a really narrow scenario where we explore the benefits of that technology. In our case, different roles are being looked at as experiences to be explored. The changes these roles could cause to the participants are analysed. We are not interested in dealing with the limitations of our systems; but in the impact these systems could have in our project. It is not about solving a specific problem using a robot or Kinect, it is rather more about investigating whether that technology can affect the therapy.

Now that our design material has been defined, it is time to decide who should be in charge of that design. In this project, several options are proposed: either the physiotherapist or the engineer/designer should be in charge of designing the system. Obviously, it is important to get the physiotherapist involved as in any other Health Care project [8] [7] [57], but the main problem might be where and when to incorporate them. Then, we could think in the same way as [6] and create a tool that allows the physiotherapist to develop the movements that the robot should do. This methodology is dismissed in
our project due to our own limitation: the physiotherapist would not spend the required amount of time learning to use the interface and would not be interested in the project. On the other hand, the engineer could just design the whole system without asking the physiotherapist and simply test it whenever it would be finished. This way we would forget the importance of Human-Computer Interaction (HCI) during the design [31] [41] as it could not succeed in this Health Care context where everything must be firstly checked and approved by a medical expert. At the end, it was decided to leave the design process to the designer, but to incorporate the physiotherapist in the earliest stages of the process. The physiotherapist will demand and specify which movements they want to be developed, and then approve them or correct them through a video analysis before the product is tested in real life.

Once the design material (what) and the designer (who) are established, only deciding how this is going to be done is left. During this research project, as it was explained before, an iterative process, where each iteration adds a new functionality to the system, is followed. Still, it is not clear which method rules those iterations. The research method used during this project is the “research through design” defined by Zimmerman et al. in [67]. This method is a type of design research and allows to iteratively design artifacts in a creative way. Using the research through design model, Zimmerman says [67]: “interaction design researchers integrate the true knowledge (the models and theories from behavioural scientists) with the how knowledge (the technical opportunities demonstrated by engineers)”. This methodology seems to be the most appropriate in our scenario, where the movements are created by the designer together with the physiotherapist. The implementation of the movements is gradual and progresses along several phases and iterations. Besides, the research has different approaches in each iterations (semi autonomous versus autonomous, videos versus three-dimensional feedback, etc.) that will contribute to add new knowledge in order to develop a future final system.

Finally, in order not to fall in love with our initial idea of using a robot, two different settings are developed during the first iteration: the robot as feedback tool and a virtual representation of it. This virtual representation is able to give the same feedback, but using a different setting (screen-based feedback).
Chapter 2

Literature Framework

In this section, a theoretical framework is presented. Through this framework, the reader can be placed in the current environment where different pieces of technology as tangible interfaces, robots, video games, etc. are used in a Health Care context. First, a compilation of exergames and different technologies used to encourage the elderly to exercise will be described, trying to introduce several alternatives to our solution. Then, the robots will be closer looked at to describe more in-depth how they are used within a medical setting. Next, a general approach will be shown, where the specific needs for the elderly that the project must deal with are introduced. To conclude, a brief explanation about the physiotherapist’s functions during a one-to-one intervention with the inpatients is described.

2.1. Introducing new technological devices into the therapy: Exergames

First of all, when the expression “exergaming” is used, according to [39], it refers to “an experimental activity in which playing exergames or any video games that require physical exertion or movements that are more than sedentary activities and also include strength, balance, and flexibility activities”.

In brief, an exergame can be considered the union of game with exercise. But what do we understand as a game?. For Katie Salen & Eric Zimmerman in [43]: “A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome”. Those games could be played while using wearable sensors [50] [44], the Wii from Nintendo [20], [19] or [30], Kinect from Microsoft [10] [33] or others [15] [24].

Our system, although it is not completely an exergame for it has neither a winner/loser nor game rules nor a game goal, it does use similar concepts to those of exergames. It uses Kinect as a tracking system, which is directly linked to games, uses a similar method to represent the feedback (a virtual representation of the robot or the robot itself) and captures the inpatients in the same way as if they were playing a game, even when they are mobilized to exercise as usual with the physiotherapist.

The greatest benefit is that exergames contribute to stimulate the elderly to do the exercises required by playing those games [9]. They integrate physical activity by playing games and therefore invite the users to exercise [37]. Even though there is a practical guideline to develop full-body motion-based games for older adults [18], not all the exergames have the same requirements. Depending on the device they choose or the place where they will be playing, those requirements could vary and therefore Gerling et al. guidelines [18] could not fit completely. For instance, two examples where priorities could change from one exergame to another are the home-based system used as a personal trainer in [50] or the web platform in [66]. In those projects, collecting and saving the medical data through the sensors required more attention than making the system adjustable to the user or making it more addictive. On the other hand, by using Wii or Kinect, the elderly can feel frustrated when the difficulty of the game is very demanding [20] so the games must be calibrated at the beginning and adjust themselves to each user’s capabilities.

Another point in favour of the related work described before, our project will consider the age-related physical and cognitive impairments [18] and try to avoid situations in which users could feel frustrated.
or stressed [20] during the design phase. Also, all the movements developed will be previously proposed and approved by a physiotherapist [5].

On the other hand, our system discards the idea proposed in [18], [5] or [10] of dynamically changing the game’s difficulty. Instead, and due to our limitations in time and resources, the movements developed will always be the same, keeping the same speed and range of motion independently of the user.

2.2. Robot within the therapy

As it was done in the previous section, a definition of robot is provided. According to Collins dictionary [12], a robot is “any automated machine programmed to perform specific mechanical functions in the manner of a man” or, in my opinion, even if it does it in the manner of any animal.

Nowadays, robots have started to be present in our daily life as pets [61] [62] or cleaning devices [63] so it should not surprise us to see them used for repetitive tasks, as it is already done in the car industry or, in our case, rehabilitation therapies. Inside this physiotherapy context, two main lines of investigation can be found: robots that help the patients by doing part of the job [40] [32] [49] or robots that encourage patients to do certain activities [46] [21] [60] [11].

Furthermore, as a clear illustration of the first line of investigation, where robots perform some functionalities that earlier belonged to the elderly, is given in [40]. In this project, a robot reminds the old people to take their medication on time by bringing it to them. Consequently, the robot takes a task that belonged to the elderly, which is to remember to take their medicine, and assumes this responsibility in order to make its owner’s life easier.

Within the second line of investigation, where robots help the users, but they do not assume any of their tasks, one example is [32]. In that project, a robotic exoskeleton is used as an assistance device which helps patients to improve their motor skills after a heart stroke. Our project is principally focused on this second line. By introducing the NAO robot in physiotherapy with old people, we provide a model to them. This model is continuously helping them by showing the correct execution of every movement or correcting them otherwise.

2.3. Specifications for the elderly

It is important to point out that the status and needs of the elderly are not the same compared to those of a senior or a young person. They can suffer deficiencies such as loss of vision and/or hearing; move slower, do inaccurate movements, may have lost some mobility in various joints or suffer certain types of illnesses as Alzheimer or arthritis [42] [9] [57].

In addition to these physical barriers, there are also cognitive limitations: changes in attention and memory [38] or more difficulties in understanding new technologies [58]. Owing to these reasons we must keep in mind that their capabilities can (and will) vary depending on the person.

Hence, one of our concerns must be the time the robot takes to reproduce the movements [20]. There should be a balance in the speed. It cannot be too fast so as not to stress the user, but it cannot cause a feeling of boredom either.

The inpatients must be able to identify the movements, understand the feedback (both for right and wrong movements) and mimic the movements while the robot is modelling them. Furthermore, it is essential that the feedback can be quickly recognizable and therefore extremely easy and fast to understand by the elderly. It is important to avoid causing a feeling of frustration to the inpatients.

Owing to their physical constraints we will use a projector to make the videos bigger and try to reduce this way their visual limitations. We have removed all audio feedback since many of them could not hear it. However, we still need to add an option to enable the use of the system by people in wheelchairs. Though they would only be able to make the upper body movements, the system must offer this possibility [20].

Finally, another of our concerns must be the possible initial rejection from the elderly to new technologies [16]. This initial rejection could be increased since we are using a robot. This question is treated in [64] where Ya-Huei Wu et al. show the great acceptance of NAO’s appearance by the elderly. In [64], they also show the worries that old people could feel when they think that a robot may substitute a person (in our case the physiotherapist). Accordingly, NAO’s functionalities are explained at the beginning of each
physiotherapy intervention. A clarification ensuring the inpatients that the robot will never substitute their physiotherapist, but rather will help him in his job is required as well.

2.4. Physiotherapist’s functions

According to our physiotherapist, there are four main functions he must deal with during one-to-one physiotherapy interventions: modelling the movements, mobilizing the inpatient, evaluating the movements and a pedagogic tutorial. During the interventions, these tasks take place as follows:

![Diagram of Physiotherapist’s functions during a traditional session]

In order to get a better understanding of the physiotherapist’s tasks, a brief summary is provided as below:

**Modelling the movement**
The physiotherapist acts as a model to display the next movement the inpatients must mimic.

**Mobilizing the inpatient**
The physiotherapist moves the inpatient as if they were a puppet. Possible reasons may be because the inpatient is wrongly making a movement or simply to give the inpatients a better understanding of the movement.

**Evaluating the exercise**
The physiotherapist is the one who decides if the inpatient is doing the execution of the movement right or it needs to be corrected.

**Pedagogic support**
The physiotherapist has to teach the inpatient the correct execution of the movements and show them the benefits of physiotherapy.

In [44], Marquez et al. changed this distribution by using two prototypes to give useful feedback to the elderly, which could allow them to self-monitor their proprioceptive skills. These prototypes helped the physiotherapist during the evaluation task.

In this project, an exploratory process consisting in changing the visual representation and the autonomy of the system is put into practice. This method allows us to introduce different systems that could change the properties of the therapy, as Segura et al. did in [44]. Concretely, two systems that return the same feedback (same movements and same robot) and share the same channel (visual) but have a different representation (two-dimensional screen versus three-dimensional robot), are introduced as models to the elderly in the first iteration. Kinect is introduced in the second iteration to make the system more autonomous.
Chapter 3

Requirements for the first iteration

Now that the reader should already have an initial idea about what to expect from this project, it is time to define the requirements. These requirements are divided into several sections according to their nature: physiotherapist’s requirements, general system design, semi autonomous system design, and autonomous system design.

• First, in relation to the physiotherapist’s point of view, it is important to keep the following requirements in mind:

  • All the movements developed must be previously proposed and approved by our physiotherapist [5].
  • The physiotherapist’s availability may be quite limited. Consequently, each time he may have to be required will produce a one week delay (waiting for his response). Therefore, it is recommended to reduce these situations to a minimum.
  • The physiotherapist can only provide or receive feedback via email. This may cause ambiguity and potential misunderstandings that will need to be fixed whenever the physiotherapist is present.

• Secondly, regarding the system design, the following requirements should be considered:

  • The system must not create any feeling of frustration or stress to the user [20].
  • The system must keep in mind the age-related physical and cognitive impairments of the inpatients [18].
  • The system must offer different grades of autonomy, to explore how this affects the therapy.
  • As the physiotherapist is unfamiliar with the system and his time for the workshop is extremely limited, the interfaces used to control the systems must be easy enough to be learned in few minutes. Briefly, the average physiotherapist should be able to learn how to use the system just through a 15 minutes explanation and demo.
  • The system must encourage the elderly to attend the therapy and exercises.
  • The system must offer a change in the roles established within the therapy.

• Thirdly, during the first iteration, a semi autonomous system will be developed based on the following specifications:

  • The system must model the movements for the elderly.
  • The model must be represented in two different ways, in our case: videos and a robot.
  • The three-dimensional feedback and the screen-based feedback provided to the inpatients must execute the same movements in order to be as similar as possible. The desired scenario is the one in which the only difference is the representation used for the feedback.
  • The system should reduce the physiotherapist’s workload by assuming the modelling task.
Finally, the automatic system phase will apply the lessons learnt during the semi autonomous system phase and will fulfill the following requirements:

- The system must incorporate the knowledge acquired during the semi autonomous phase.
- The movements will not change from the semi autonomous iteration to this new one.
- The system should reduce the physiotherapist’s workload by releasing them from the modelling and evaluating tasks.

In conclusion, these requirements are going to be used as a starting point for this project and an initial guideline for the designer/engineer. Hence, this brings us to the first iteration where the semi autonomous system is designed.
Chapter 4

First Iteration

In this chapter the reader can find all the information related to the first workshop. This chapter is split into several sections. In Section 4.1, the methods used to program NAO, their possible risks and problems, and finally the movements derived from these methods are described. Section 4.2 explains the interfaces used to control the system during the therapy. Finally, section 4.3 describes the workshop and section 4.4 shows the results and considerations derived from this workshop.

4.1. Programming NAO

4.1.1. What NAO is and why we use it

The official documentation available for the NAO robot used in this project [3] defines the robot as follows: “Robot NAO is nowadays a commonly used humanoid platform for education environment. It is a medium-sized robot available mainly for universities and laboratories for research and education purposes”. The creator is a French company, Aldebaran Robotics.

As reflected in [23]: “NAO is 58 cm height and 4.3 kg weight. Its body is constructed from white technical plastic. Some parts are grey. Inside it has a battery (DC 24 volts) for 90 minutes autonomous moving and within the accessories it is equipped with a charging adapter. NAO has 26 motors in its joints with position sensors and temperature sensors. It possesses two motors for head moving, six motors in each hand and also six motors in each leg. NAO has three tactile sensors for touching situated on his head and one bumper sensor in each foot. The force sensor is located under his feet. The gyrometer, in his chest, specifies the direction in two axes and the accelerometer the speed in three axes. In the chest are located two sonar sensors for identifying obstacles before a robot. The principal control button is placed in the middle of his chest. The loudspeakers are in his head, instead of ears. NAO possesses four microphones, all of them in head. LEDs are distributed in five parts of body: on the tactile sensor (12), eyes (2x8), ears (2x10), torso (1), feet (2x1). Vision is solved using two CMOS 640x480 cameras. One is on the forehead and second in mouth. They are the same. The visual angle is 34.8 degrees. For connectivity is possible to use the Ethernet cable or the Wi-Fi (IEEE 802.11g).”

The reasons why we selected NAO for this project are categorized into two groups:

1. Physical reasons: NAO’s technical specifications allow modelling most of the movements the elderly perform during physiotherapy interventions.

2. Psychological and emotional reasons: It is proven in [64] that NAO is a well accepted robot by the elderly. Therefore, it is easier to introduce this new technology in their lives avoiding the possible initial objections. Furthermore, the use of a robot helps the inpatients not to lose their interest in the physiotherapy by making it more interesting [59][57].

4.1.2. NAO’ SDK

In order to program NAO’s movements, we used “Choregraphe”, “Naoqi”, NAO’s C# libraries and “NAOsim”. This software is included in the Aldebaran’s SDK.
4.1. PROGRAMMING NAO

Choregraphe

In [4], Choregraphe is defined as: “Entirely designed and developed by Aldebaran Robotics, Choregraphe is the programming software that lets NAO users create and edit movements and interactive behaviours simply. The intuitive graphic interface, standard behaviour library, and advanced programming functions meet the needs of novices and experts. Anyone can compose behaviours by simply dragging/copying from the library or creating personalized boxes and saving them to personal libraries. You can explore event-based, sequential, or parallel programming; the time line lets users program with schedule logic. The preprogrammed behaviour boxes are easily configurable, but you can also create your own using the Curve Editor to edit movements or by writing them in Python script. Combining these approaches creates vast opportunities in NAO programming, with or without entering the complexity of code. Choregraphe understands the Urbi and Python languages, so it can directly call separately developed C++ modules.”

Choregraphe is therefore a program where programmers can drag pre-defined movements and drop them into the new behaviour programmed for the NAO robot. This program also facilitates the creation of new movements. There are two different ways to create these new movements:

- Manually: The programmer places the robot in the specific position they want to create. Then, they store the joint values that are needed.
• Through the interface: the programmer will change the joint values (that they want) one by one (see Figure 5.5) until the robot reaches the desired position. This option is preferable when high precision is required to perform the movements.

**Naoqi.Net & C#**

Naoqi.Net allows the user to call any NAOqi method from most Microsoft .Net languages. It is one of the easiest ways to program NAO from a remote Windows based machine. The limitation of Naoqi.Net is the fact that it can only be used on remote Windows machines. Therefore, it cannot be used on the robot. Naoqi does not implement NAOqi’s ALModule class, consequently, it cannot receive event notifications. [4]

**NAOsim**

NAOsim allows the user to launch a simulated NAO movement in a virtual world. In this project NAOSim has been used to design all the screen-based movements. When this program is connected with Choregraphe (where the movements are developed), it simulates the desired movement.

![Virtual NAO](image)

**Figure 4.3: Virtual NAO**

### 4.1.3. Design proposed: movements to be developed

First of all, in order to make the implementation of movements possible, the physiotherapist is consulted. During this enquiry, the physiotherapist is asked for the movements generally performed during geriatric physiotherapy interventions, as well as the most common errors done by the inpatients while performing them. Owing to this enquiry, some specifications related to the pre-established movements given by the physiotherapist (Appendix A) are defined. Below, the reader can find the implementation process of these movements. The process consists of iterative cycles composed of the following steps:

1. The physiotherapist describes the required movements.
2. These movements are designed and programmed into NAO.
3. NAO is recorded while modelling the movements, and the recorded videos are sent to the physiotherapist.
4. The physiotherapist responds with medical feedback and the process continues in step 2 until the correct movements are obtained.

This is a complex process due to the unknown response of the elderly to the movements. The solution proposed in [52], is to keep all the variables under control. In order to achieve this, we must simplify the movements development process. Initially, during the movement design, the emphasis is put on the definition made by the physiotherapist. The next step is to balance the robot during the session, so that it makes more realistic movements and, finally, to adjust the robot’s speed.
4.1.4. Risks and problems

During the programming of NAO, some software related problems appeared; the most important are summarized here:

- Setting up problems owing to an error in Aldebaran’s C++ libraries.
- Migration of the programming language used from C++ to C#.
- Complexity of the movements in which NAO should stand on one leg. What is normal and intuitive for us, is not so for NAO. When programming NAO, it is necessary to explicitly program how to do each movement, i.e. the programmer must manually modify each joint.

Regarding NAO’s hardware, it has several limitations:

- Physical constraints: It cannot flex its arm and touch its shoulder with its hand because the plastic covers would collide between them.
- NAO needs some type of power to be able to work, this implies the usage of batteries. Thus, it is possible that during the workshop we need to plug the robot to the electric network.
- The stiffness in NAO’s joints is another point that we are concerned about. Since the robot is going to be used for long time, it is possible that the joints in use become warmer and subsequently lose accuracy, causing NAO to fall down. In order to avoid this, we suggest that the robot continuously change the joints in use: if it makes a movement that may cause a load in its right leg, the next movement should try not to use the same joints, for example, playing a left arm movement next.

4.1.5. Design: early results

As a result of the iterative process, NAO is programmed to perform 9 exercises. These exercises are performed with regularity in the rehabilitation sessions at the assisted living facility where our physiotherapist works. In addition to the 9 pre-established movements, a set of typically related wrong movements is also designed. These wrong movements are frequent mistakes or inaccuracies that inpatients usually perform during the execution of the required movements. For example, during the “flexion of the shoulder” exercise, some of the elderly tend to lean their torso backwards at the end of the movement. Both right and wrong movements are available for NAO virtual and physical representation. During the study, the physiotherapist is free to trigger the different movements - either the “right” or the “wrong” movement - whenever necessary. When using the wrong movements, the physiotherapist has two alternatives, depending on whether the virtual or physical NAO is used. In the virtual condition, the physiotherapist needs to click on the interface provided (described in the next section) to trigger the wrong movement. On the other hand, in the physical condition, the wrong movements are triggered by touching one of the sensors on NAO’s head. Below, both the right (bullet marks) and then their belonging wrong movements (star marks), are listed:

- Flexion of shoulders
  - Combined with back leaning
- Abduction of shoulder
  - Combined with flexion of shoulder
- Extension of shoulder
  - Combined with a stoop
- Hands opening and closing
- Pronation and supination
- Abduction of hip
4.2. PHYSIOTHERAPIST’S INTERFACE

- Combined with flexion of hip
- Combined with extension of hip.

- Flexion of hip
  - Combined with flexion of knee

- Extension of hip
  - Combined with abduction of hip

- Flexion of knee
  - Combined with flexion of hip

The following movement is dismissed owing to the fact that it is impossible for NAO to perform it:

- Flexion of arms

In order to create the virtual representation of NAO we used the NAOSim software. NAOSim is provided by Aldebaran and it creates a virtual environment to test NAO’s movements. Afterwards, this virtual NAO is recorded while it is performing the same movements, and the videos are stored to be used later on in the workshop.

4.2. Physiotherapist’s interface

4.2.1. NAO’s programming interface and user interface

In order to communicate the physiotherapist with NAO, a computer interface is created. Through this interface the physiotherapist can select the movement he wants to display in NAO. One of the design aims for this interface is to keep it as simple, consistent and understandable as possible. Therefore, there is neither a graphic design analysis nor any other extra complexity.

All the interface implementations are carried out using an iterative cycle where, first of all, an initial design is drawn. Next, this early sketch is subject to be reviewed by an expert group in HCI. The feedback provided by this group is used to start the cycle again. So the process starts again and repeats all the development phases, being these: sketch, prototype and final implementation in C#.

As a first proposal, the interface showed in Figure 4.6 is designed. This proposal is based on the clear distinction between arm-based and leg-based movements. So, by clicking on the arm/leg icon, the available movements would show up in the main box. Then, if any of those movements were selected, both right movements (green box) and wrong movements (red box) linked to it would appear on the two long boxes at the bottom.

![Figure 4.4: Hardware and software representation of a movement](image)

(a) Flexion of shoulder: NAO  
(b) Flexion of shoulder: Choregraphe

Figure 4.4: Hardware and software representation of a movement
The main problem this proposal entails is the time the device takes to change between a right and wrong movement. To make this transition, the robot must stop the current movement and then launch the new one. This transition could take from 20 seconds to 3 minutes depending on the stage and the type of movement that the robot were currently performing. This problem is obviously inadmissible, so a new cycle focused on reducing this problem was designed.

The proposed solution is to incorporate the wrong movement together with the right ones. This is possible by using the tactile sensors that NAO has on its head; but it also demands a reimplementation of the movements (See Figure 4.7). Now, if the user needs to trigger a wrong movement, NAO’s head sensors must be pressed. Thus, depending on the sensor pressed, NAO changes from the right movement to the selected wrong movement.

As a result of this change, the laptop’s interface is modified into a new one (see Figure 4.8). In this new interface, all the movements are permanently shown on the screen. The distinction between the arm-based and leg-based groups is kept to make the finding of a movement easier. In this way, if the user selects a movement, a pop-up appears to make the user choose between the left or right side (flexion of left or right arm for example) and the associated wrong movements to the selected movement are allocated in relation to the sensor that triggers it.

Finally, the physiotherapist uses this last interface to manage the two different systems: physical NAO and virtual NAO. In this way, the possibility of an influence from the interface into the workshop...
4.3. Workshop

4.3.1. Set-up and methodology

The workshop consisted of one-to-one sessions. Thirteen inpatients participated in our study. Two researchers were present during the rehabilitation sessions. We employed two cameras, that captured
different angles of the scene. At the end of each session, the inpatients signed a form in order to allow us to use all the data collected. We followed the randomized trial [53] where at least two groups are created: a control group and variable study groups. At the beginning of each session, each exercise is randomly assigned to one of the three conditions listed below, defined by the following therapy environments:

1. Physiotherapist alone (control group): The exercise is done as usual.
2. Physiotherapist + virtual: The physiotherapist uses the virtual representation of NAO to model the movements the inpatients should mimic, and to provide them feedback as well.
3. Physiotherapy + robot: The same as in 2), but using the NAO robot.

Finally, NAO always models a defined number of movement repetitions: 5 times for a right movement and 3 times for a wrong one.

4.3.2. Analysis

The following methods have been carried out for the purpose of analysing all the data collected in the workshops:

- Direct observation
- Questionnaires and semi-structured interviews with inpatients and physiotherapist
- Video analysis

Our original observations are confirmed after the video analysis. For the purpose of measuring and detecting our findings, a researcher watched the videos several times, looking for the following events:

- Movements recognized by the inpatient (whether from virtual or physical NAO)
- Inpatient’s synchronization with physiotherapist, virtual NAO and physical NAO.
- Physical contacts between the physiotherapist and the inpatients.
- Errors made by the physiotherapist while he is managing the system.
- System’s possible improvements.
- Changes in physiotherapist’s behaviour.
- Inpatients’ interactions with NAO
4.3.3. Interviews

In order to learn the inpatients' opinions regarding their preferred feedback system, and what their opinion about NAO is, a semi-structured interview has been designed (see Appendix C). These interviews are done by the physiotherapist or the researchers after the inpatient has finished their exercises.

As a result, even if the interviews related to NAO and its feedback were useful, the comparative between the three systems did not work. That setback is owed to the fact that the inpatients were inclined to satisfy us rather than expressing their own ideas. They tended to answer with the last word we had said, for example, if we were comparing the video against the robot they could change their mind depending on the emphasis we made in either of those words.

Another problem we faced, is our initial idea of grading the systems. The inpatients had to select a grade between 1 to 5 as in the following example: being “1” they clearly prefer the intervention with the physiotherapist alone and “5” they prefer it with physiotherapist + robot:

- □ 1 Physiotherapist
- □ 2
- □ 3
- □ 4
- □ 5 Robot

They did not really understand the purpose of these grades. In consequence, it was decided to suppress the comparison from our study, keeping only the interviews about NAO and its feedback.

4.3.4. Interviews’ forms

This part includes a summary of the inpatients’ answers to our forms.

1. To the question “What do you think about this robot?” we got replies as:
   - Inpatient 1: “One never gets tired of watching it” or “it performs the movements pretty much better”.
   - Inpatient 2: “I wish I could buy it”
   - In general, NAO got praises as beautiful, cool or easy to understand.

2. To the question “Do you think the robot’s movements are natural?” and “Do you know which movement you have to execute when you are watching the robot?”:
   - Everyone answered affirmatively.

3. To the question “Do you consider the robot could perform movements that you cannot?”:
   - Everyone except one inpatient answered “No”. The person who responded “Yes” argued that it was because of her limitations.

4. To the question “Would you like the robot to stay here or do you prefer the video?”
   - All of them responded they preferred the robot.

4.3.5. Results and observations

The video analysis enabled the study of different behaviours during the sessions. Consequently, special attention has been placed on what the physiotherapist does and how he interacts with the inpatients depending on the condition of the therapy: alone, with Physical NAO (PhyNAO) or with Virtual NAO (ViNAO). Following this criterion, several results are detected:
1. There are changes in the physiotherapist’s location within the room distribution depending on the condition.

One of our findings refers to where the physiotherapist places himself during the sessions (see Figure 4.9). Under the physiotherapist alone condition, he tends to remain in front of the inpatients. However, under ViNAO or PhyNAO conditions, the physiotherapist places himself next to the inpatients (both facing NAO). This last position changes when the physiotherapist needs to model the movement and correct the inpatients. In these cases, the physiotherapist places himself forming a triangle.

![Physiotherapist facing the inpatient](image1)

![Physiotherapist next to the inpatient](image2)

![Triangle position created by the physiotherapist, NAO and the inpatient](image3)

Figure 4.9: Physiotherapist’s positions example

2. In terms of roles, it is also important to point that under ViNAO and PhyNAO conditions, the physiotherapist usually made the same movements at the same time as the inpatients. This occurrence happened 34 out of 56 times under ViNAO condition and 36 out of 51 times under PhyNAO condition.

3. The number of physical contacts between the physiotherapist and the inpatients also vary depending on the condition.

According to [17], one of the factors that measure the interaction within the therapy is the interaction dimension, which has three different themes: “ways of contact,” “therapeutic process” and “structure of treatment”.

Centring on the ways of contact, an increment is observed in the number of times the physiotherapist has a physical contact with the inpatients. For instance, those contacts could be placing or sliding his hand on the inpatient’s shoulder or back (see Figure 4.10). This happened 2 times under
physiotherapist alone condition, 7 times under ViNAO condition and 13 times under PhyNAO condition.

4. Under ViNAO and PhyNAO condition the process for mobilizing an inpatient changes. There are certain reasons, as a wrong execution of a movement or a misunderstanding of it, that could cause the physiotherapist to mobilize the inpatient. This is done in order to show the inpatient how to do the exercise correctly. Still, there are differences between the three sets of conditions: on the one hand if the physiotherapist is alone, he has to stop modelling the movement to move the inpatient; on the other hand if they are using an external model to show the movement, the physiotherapist could mobilize the inpatient while NAO is still modelling the movement. In addition, the physiotherapist can make use of NAO to point out what the patient is doing wrong.

According to the physiotherapist, this is one of the clearest benefits from using an external model. The inpatients need to follow some model, otherwise they would simply stop doing the movement. So this way, even if the physiotherapist needs to mobilize them, the inpatients can keep making the movement and do not break the dynamic. The physiotherapist needed to mobilize the inpatients 4 times under physiotherapist alone condition, 15 times under ViNAO condition and 7 times under PhyNAO condition.

It is interesting to mention that three certain movements required more mobilizations: the abduction of shoulder, flexion of shoulder and extension of shoulder. Two of these are movements in which the NAO’s limitations are clearer [13].

5. The elderly synchronize themselves with the robot under certain conditions.

Throughout the workshop, it has happened that patients take their synchronization with NAO to the extreme. Some examples of this are: two inpatients stood up at the same time than NAO (see Figure 4.12) without it being requested, another example, during the abduction of shoulder
exercise, some inpatients stopped in the middle of it just as NAO does (for technical limitations), instead of doing it at once as they usually do.

![Figure 4.12: Patient standing up at the same time than NAO](image)

Also, the speed of the movements plays a major factor in causing this synchronization and capturing the elderly’s attention. Then, whenever the speed of the movement is similar to that of the inpatients, they usually pay more attention to the movements NAO performs [13]. In cases where the speed is different, the inpatients are less focused. Many of the inpatients whose speed is similar to that of NAO, seem to synchronize their movements in order to perform them at the same time as the robot. In exercises in which NAO is slower than the inpatient, such synchronization is not that apparent. Besides, this synchronization and mimicking lead to other interesting effects:

- Some inpatients slow down in order to match NAO’s speed. This decrease in the movement execution speed leads to an improvement in the technical quality of the inpatients’ movements [13].
- On the other hand, a negative side-effect is observed: some of the (hardware) limitations of the robot affect the performance of the exercises, leading to movements with less amplitude [13], i.e. the inpatients demonstrate a shorter reaching distance than what they are capable of, as they are mimicking the smaller range of movement of NAO.

![Figure 4.13: Patient and physiotherapist mimicking virtual NAO](image)

6. In order to check if the interfaces are valid, the errors committed when using these interfaces are counted (see Figure 4.8).

At the same time we introduce technology into the sessions, we are also introducing the possibility of making a mistake by using it. Hence, the physiotherapist was 9 times wrong when trying to select the next right movement for PhyNAO, 1 for ViNAO and 4 times when he was trying to make a wrong movement for PhyNAO show up.
7. Validation of NAO in geriatric physiotherapy contexts and acceptance by the inpatients.

Because of the robot not being originally designed for physiotherapy, there is a risk of inappropriate working. In order to recognise this possible problem, the inpatients are requested to identify NAO’s movements. At the end, when the therapy is over, they also have to respond to some questions about NAO’s appearance and movements.

As a result, all the elderly could recognise most of the movements without any help, but in a few cases they needed the physiotherapist’s support (especially when the movement was constrained by NAO’s limitations, for example, extension of hip). During the interviews, they revealed that they did not feel any fear caused by NAO, just the opposite, they saw it as a toy. With questions as: “do you think the robot’s movements are natural?” and “do you consider that the robot could do some movements that you cannot?”; we focused on discovering whether they think that the movements seem realistic and natural, or on the other hand, it is only possible for NAO to complete them.

All inpatients answered that they could perform all NAO’s movements except, of course, the ones related to one of their additionally physical problems as for example a joint with prostheses.

4.3.6. Design improvements: changes done in situ

During the workshop, some possible improvements showed up. It was decided to program some of them in-situ. These quick improvements actually emerged to be crucial to the project. It is even more important when the target group are old people. One of the problems that arose is that the movements programmed, although recognisable by the seniors, were not realistic. These movements did not reflect the authentic inpatients’ movements. Then, it was decided to approximate our designed movements as much as possible during the workshop days. As a result of this we performed the following improvements:

- Redesigning of wrong movements:
  - Abduction of hip combined with flexion of hip
  - Abduction of hip combined with extension of hip

- Addition of new wrong movements:
  - Extension of shoulder – Hand swinging
  - Arms moving during pronation and supination
  - Extension of hip – Lean forward

- Redesigning of right movements:
  - Open/close hands – It is done with both hands at the same time.
  - Open/CLOSE hands – Added 1 second between the open action and the close one.

- Acceleration of movements:
  - Flexion of shoulder
  - Abduction of shoulder
  - Flexion of knee
  - Flexion of hip
  - Extension of hip

- Flexion of shoulder – angular amplitude enlarged.

- The number of repetitions was set to 10. The physiotherapist complained the robot stopped modelling too early, so it was decided to extend the number of repetitions for each right movement.

- Updated of the virtual NAO version with the new right and wrong movements
4.4. Findings and considerations

In addition to the results, the research team came up with the following findings:

1. Extra task

   Whereas the modelling task was now performed by NAO, another external task had been added to the physiotherapist: the control of the system. With our method, a workload reduction has been accomplished in terms of modelling the movements and evaluating the patients. But now the physiotherapist is the one who must synchronize the system with the exercises that patients will do. This was especially visible when one of the researchers took control of the system, releasing the physiotherapist from this function. From that moment, the physiotherapist assumed a more active role, increasing his pedagogic function towards the inpatients. The physiotherapist placed himself next to the patient, observing him, encouraging him through conversation or physical contact and correcting him if needed. In this manner, the “ways of contact” within the session [17] [25] are generally improved.

 Moreover, with the inclusion of NAO in the therapy, the sequence of actions in the interventions changed slightly (see Figure 4.14).

![Diagram](image)

**Figure 4.14: Physiotherapist’s functions**

(a) Physiotherapist’s functions during a traditional session

(b) Physiotherapist’s functions during a session with NAO

2. Roles within the therapy

   By means of the allocations where the physiotherapist were positioned (see Figure 4.9), it is observed how he turned from a role where he was playing in the same team with the inpatients, to the opposite one, as the inpatients’ supporter. This distinction among roles is important from the inpatients’ point of view. So when the physiotherapist takes their side, they play against NAO, trying to beat it; the session becomes a game. Otherwise, when they are one in front of the other, the session ends up being just about following the physiotherapist’s instructions. This causes a decrease in conversational interaction, which as showed in [25], makes part of the interaction dimension of the therapy, helping physiotherapists improve their relationships with their patients.

3. Ways of contact.

   It was observed that the change among the roles caused a fluctuation in the number of physical contacts as aforementioned in the results. Sometimes, that physical contact is required to express confidence and proximity [25] [17], and entails an improvement in physiotherapist and patients’ relationships.

   The physiotherapist’s position according to the inpatient and whether he is doing the exercises in the same way as the inpatients or at the same rhythm could also be included inside the “ways of contact” that [17] analyses. If this is accepted as part of that interaction dimension, it is valid to affirm that introducing NAO into the therapy causes an increment in this interaction dimension, consequently improving the physiotherapy sessions.
Chapter 5

Second Iteration

In this chapter, Kinect’s contribution is presented. During this second iteration, Kinect is added and the NAO robot is still used as feedback representation for the elderly. Incorporating Kinect adds an increment in the system’s autonomy. This change in the autonomy will allow us to explore how it affects to the therapy in terms of roles distribution. In addition, changes within the physiotherapist and the inpatients’ behaviours are analysed.

Besides the inclusion of Kinect, all the knowledge acquired in the first iteration is incorporated to the new system. Therefore, NAO’s movements are improved and methods to solve errors found during the first workshop are covered in this chapter.

5.1. Programming Kinect

5.1.1. How Kinect works

The Kinect device was originally developed by Microsoft for its Xbox 360 video game console. Microsoft provides an official SDK to program it.

According to [35], Kinect consists of: a Red-Green-Blue (RGB) camera, three-dimensional depth sensors, a motorized tilt and a multi-array microphone. Thanks to them, Kinect can track a person’s full skeleton, recognize their gestures or voice, and other functionalities.

The main functionality used in this project is the full skeleton tracking function. Kinect uses two mechanisms to perform this task: a projector and a Video Graphics Adapter (VGA) infra-red camera. The projector emits laser over an area to create a “depth field”. This helps separating the user from the rest of the objects in the environment. Kinect receives Interference Rejection (IR) noise from all the pixels, which is turned into colour values. Depending on their distance to the device, the objects get a red, green, blue or grey colour, being grey the colour assigned to the furthest one from Kinect [47] [28]. The software then takes the images and sends them through filters that help the device distinguishing the user and the rest. After that, Kinect uses this information to emulate a skeleton with mobile articulations. This process is repeated 30 times per second [56].

5.1.2. Using Kinect: FAAST

A framework called FAAST [54] is used in this thesis. This framework basically makes use of Kinect’s skeleton functionality to compare the joints between each other. The program is divided into the following tabs:

- Sensor tab: We must select which tracker we are going to use, i.e., the drivers we will use to control Kinect. In our case, Microsoft’s tracker is selected.

- Server tab: We must deselect the “automatically assign skeletons” option and confirm that the value 1 is established in the section “tracker 1”. The rest of the sections must be left empty. This way, Kinect is forced to analyse just one user’s movement.
• Gestures tab (see Figure 5.1): We have to specify one by one which gestures will be recognized by Kinect and their output in case Kinect recognizes them. Each gesture consists of inputs and outputs. Outputs will only be executed if all the inputs are satisfied. Below we explain step-by-step how a gesture is created:

First of all, we must click on the “New Gesture” button. As we can see in Figure 5.1, a gesture has been created, but it is still empty. Once we have created a new gesture, we must define both inputs and outputs. By clicking on “Inputs” the Add button will become clickable. If we click on it we must see the same as in Figure 5.1. We now have to choose among the different inputs available in the framework:

• Add body constraint (see Figure 5.2): the user is able to choose among the options shown in Figure 5.2:

As always, it is easier to understand it with an example. Assume we have selected: Lean / Forward / at least / 10 / degrees. In this case, the gesture is activated whenever the user leans the trunk at least 10 degrees forward in respect to their waist.

• Add position constraint (see Figure 5.3): the user must select the body part that will be used as guide mark. As an example, if the user selects head / to the right / left elbow / at least / 34 / centimetres then, this input will be activated any time the user’s head is situated at least 34 centimetres to the right from the left elbow.

The definition of the remaining inputs is not presented, since they are not employed in this thesis. If the reader should want to investigate more about this framework, he is referred to [54].

As we did with the Inputs in Figure 5.1, we must click on “Outputs” and then, click on the Add button. This time we obtain different options (see Figure 5.4):

As we did last time, we will only describe the outputs used during this thesis. For further information you can examine it on [54].
5.1. PROGRAMMING KINECT

Figure 5.3: FAAST Input: position constraint

Figure 5.4: FAAST Outputs

(a) Output: pressing a key

(b) Output: holding a key

(c) FAAST Output: Add type event

Figure 5.5: FAAST Output: Add keyboard event + Add type event

- Add keyboard event: FAAST simulates the pressing or holding of a key on the keyboard.
- Add type event (Figure 5.5a and Figure 5.5b): FAAST writes the text that the user has introduced in the box.

5.1.3. Risks and problems

In this section, some scenarios where Kinect could encounter certain problems are described. Those problems might be due either to Kinect itself or to the use of FAAST framework:

1. When there are several users in front of Kinect, all their movements are tracked.
In our case, we need to track just one user at a time insomuch we just want to track the inpatient’s movements and cast aside any other. We can achieve this if we follow the instructions described in Section 5.1.2.

In addition to this scenario, there is a situation when the framework might not work correctly: User 2 hides user 1 from Kinect’s view. From that moment, until user 2 goes out from Kinect’s view, Kinect will track user 2 instead of user 1. Therefore, in terms of physiotherapy session concerns, the physiotherapist should not cross between Kinect and the inpatient. If he needs to cross, he could do it by going behind the inpatient without disturbing the system. In this way, he does not impede the session. This limitation is caused by the framework, but it could be avoided by more thorough programming. Actually, there are several options already implemented in Kinect SDK. These options allow the user to select which skeleton should be tracked, for example, the most active user.

![Figure 5.6: Kinect error: two users in front of Kinect](image1)

2. There are several users in physical contact in front of Kinect:

The following scenario is drawn in order to make it easier to understand this problem. Assume that the physiotherapist needs to correct the inpatient. Therefore, the physiotherapist goes and moves inpatient’s arm. In these situations, it could happen that Kinect did not respond as it should, confusing both skeletons (see Figure 5.7).

![Figure 5.7: Kinect error: two users after a physical contact between them](image2)

3. Kinect and the user’s position inside the room: It is important to know that Kinect’s placement has several requirements in our scenario:

- It should be located at a height approximately equal to the inpatient’s hip.
- The inpatient should be doing the movements in front of Kinect and his skeleton should be shown in the middle of the screen.
- The inpatient should be located in a place where their feet lie on the bottom of the screen and their hands do not get out of the screen when they lift them. In order to make it possible, we can modify both Kinect’s tilt and its distance between the device and inpatient.

5.2. Requirements

In order to provide a deeper understanding of the aims pursued while introducing Kinect and the design decisions made, a list of requirement is provided for the new system:
5.3. Design decisions: incorporating knowledge acquired

5.3.1. Looking for autonomy

The problems appeared during the first iteration are treated into this second iteration. In order to refresh the reader’s memory, a brief summary is introduced below:

- The physiotherapist complains that he has to launch the same movement several times. This problem was negotiated during the section 4.3.6; as a temporal solution, the number of repetitions was increased to 10 for right movements.
- There is no way to stop the movements. Sometimes, when the physiotherapist was trying to select a movement, he made mistakes when trying to select the desired one. There was no way to stop it, so he had to wait until NAO finished.
- An extra control task is added to the physiotherapist’s functions.

For the purpose of solving these problems, it is proposed to force NAO to model infinite repetitions of every movement. Consequently, a reimplementation of the movements is required. This software modification is translated into a conversion from a flow diagram, where exceptions are treated at the beginning of each cycle (See Figure 5.8), to a state machine, where the exceptions are treated instantaneously (See Figure 5.9).

Some of the other aims in this second iteration were to increase the system’s autonomy and reduce the added extra control task. In order to fulfill these aims, Kinect is introduced to the system. With Kinect integrated in the project, there would not be any need to maintain any interface. The right movements can be launched automatically, as well as the detection of wrong movements.

Therefore, with Kinect working with the system, the inpatient’s skeleton is always tracked. Whenever the inpatient’s skeleton gets a pose that fits in any of the specific postures previously defined, Kinect writes the name of that posture into a text file. Then, the application that is running on the laptop...
reads and processes that variable. If it is a valid order, the laptop sends it to NAO who will model the right/wrong movement.

Now that NAO is modelling the movement, two questions could come to our mind: when will NAO switch from a right to a wrong movement?, and how can the physiotherapist stop the movement if it has infinite repetitions?.

The process followed to change from a right movement to a wrong one is:

1. The wrong movement is recognized (as done with the right one).
2. If the recognized wrong movement is associated to the current right movement, NAO will model it.

On the other hand, to stop the robot, the physiotherapist can stop the current movement by pressing the frontal sensor on NAO’s head once. It is important to highlight that the wrong movements have also infinite repetitions now. Therefore, if the sensor is pressed, the robot will come back to the right movement. Then, if the user presses the sensor again, the robot will stop definitely.

The reason why the wrong repetitions are done in an infinite way is to provide the physiotherapist as much time as he may need to explain what the user’s mistake was.

Additionally, because of a lack of robustness in the system, an alternative solution is developed and explained in the next section.

5.3.2. Building a back door for autonomy

As it was introduced in last section, the system’s lack of robustness suggests the idea of designing a rescue plan. In our case, the system could interpret some movements that the inpatient might do unconsciously as valid. For example, whenever a person is sitting down on a chair, a flexion of hip is done. That movement should not be recognised by the system even if it is a valid movement. Hence, every time a movement is recognised while NAO is stopped, the physiotherapist will be asked to accept or reject the movement by using a wireless mouse (see Figure 5.10): left click to accept it or right click to reject it. On the other hand, if NAO is already modelling a right movement, the new movement is discarded.

Despite our tenacity in pursuing a total autonomy of the system, a minimalistic interface had to be designed to be able to interact with the system in case of emergency. The result of this process is the interface in Figure 5.11.
This interface consists of exactly the same movements provided during the first iteration, and a large button to stop them by clicking on it twice. This large button acts as NAO’s frontal head sensor.

It could happen that Kinect did not recognise a movement. In order to cover this scenario, a chance to manually trigger the movement is added:

- Right movement: The physiotherapist selects manually the desired movement from the list and sends it to NAO.
- Wrong movement: NAO’s head sensors still have the functionality of triggering the wrong movements. Now, the difference is that only the middle and back sensors are used. The information related to which sensor launches each movement is deleted. Even if the removal of this information could seem an error, in fact, this data is not necessary. In our scenario, each right movement has maximum two possible wrong movements associated, and the physiotherapist knows them perfectly (he would also be seeing them on the inpatients when he wanted to select them). Each of these wrong movements is clearly directed in one direction: forward, neutral or backward. So, they can be easily sorted among the middle sensor for forward-based movements and the back sensor for backward-based movements. Regarding the neutral-based movements, they are placed in the sensor that is not being used by the other wrong movement (it cannot happen that there are three wrong movements associated to the same right movement).
5.4. Set-up

The workshop consisted of various one-to-one sessions. Fourteen inpatients participated in the study. Two researchers were present during the rehabilitation sessions. We employed three cameras, capturing different angles of the scene and the laptop’s screen was recorded as well.

The inpatients are placed in front of Kinect and NAO at an appropriate distance. Once everything is set (see Figure 5.12a), the therapy starts by requesting the inpatient to perform a certain movement (1). Then, Kinect should recognise the movement and ask for the physiotherapist’s confirmation (2). When the physiotherapist acknowledges the movement (3), NAO starts modelling it (4). In case Kinect does not recognise the movement (see Figure 5.12b), a researcher triggers NAO’s required movement (1). No confirmation is required this time so NAO starts modelling the movement immediately (2) and Kinect tracks the inpatient as before (3).

![Movement triggered by the elderly](image1)

(a) Movement triggered by the elderly

![Movement triggered manually](image2)

(b) Movement triggered manually

Figure 5.12: How a movement is launched

5.5. Workshop

5.5.1. Analysis

For this second iteration, the workshop analysis is done through direct observation. Hence, there is not any video analysis or interviews. The decision of not including the video analysis was taken due to the current amount of work on this thesis. However, this data is still available for future research. This workshop’s analysis is focused on showing certain problems that happened during the workshop and on designing recommendations for future work.

5.5.2. Observations

During the second workshop, when the system was being tested, several events happened that pointed out some wise and wrong design decisions. Below, a brief discussion about the influence of our system into the therapy is described:

1. Kinect does not recognise the inpatient’s skeleton: some of the wheelchair inpatients were recognised only sometimes.

   In the situations where the researchers cannot claim the accomplishment of a 100% full-working autonomous program, having a secondary manual operated option becomes necessary.

2. Kinect unfairly recognises a wrong movement.

   The system is not adjustable to the inpatients. Therefore, Kinect could consider that the inpatient is doing something wrong when, in fact, the problem could be due to a physical limitation caused by a prosthesis.

   For the purpose of solving this, an in-situ programming is required. This system adjustment can be done by an engineer introducing the personal data of each user or by the physiotherapist through a framework.
3. The physiotherapist feels more comfortable when other person is controlling the system.

   Physiotherapist: “... same with the mouse, I do not like it, I do not like any device that compels me to be more focused on a screen than on the inpatients.” or “I want to have both hands available to grab the inpatient if necessary”. These sentences express how the physiotherapist felt when he had to control the system through the mouse. Even if he only had to click once to accept/reject the movement or twice to stop it.

   The physiotherapist also proposed a speech recognition system where he could say the movement to be done and a key word to stop it. This option was also implemented before the second workshop, but discarded because of the inaccuracy of NAO recognising words. NAO’s speech recognition is only reliable if the physiotherapist is really close to the robot (20 centimetres), which is not our scenario.

4. The physiotherapist complains about the waste of time confirming the movements requires. He is usually looking at the inpatients. He does not realize that the movement has been recognised and shown on the screen for confirmation.

   This problem opens a completely new discussion. It is necessary to give feedback to the physiotherapist; but when and where should it be displayed? As a quick solution, the laptop where the physiotherapist receives the feedback was moved from its original position (next to NAO) to two new different places: in front of the physiotherapist and next to the inpatients.

   As a result, it is observed that the physiotherapist feels more comfortable if the feedback is allocated closer to the inpatient. Furthermore, he is quicker realizing any change in the feedback.

5. A loss of synchronization between the inpatients and NAO happened.

   The synchronization achieved into the first workshop (see Section 4.3.5) [13] disappears when the dynamic is changed. This could be caused by the change while starting the movement. At the first iteration, it was NAO who started modelling the movement, whereas in this second iteration, the inpatient starts modelling and NAO follows them.

   As conclusion to this project, a guideline which involves certain aspects related to a reliable design within geriatric physiotherapy interventions context is described in the next chapter.
Chapter 6
Discussion, Design Conclusions and Future Work

In this chapter, a brief discussion and conclusions of this thesis are presented. Then, a set of guidelines is proposed. These guidelines should be considered as an opinion based on all the experience acquired during the workshops and previous work. In the following, we will try to clarify the design decisions taken during the design process. In order to make the guidelines clearer, they will be divided into the next sections: model design, Kinect, and physiotherapist’s considerations and others. At the end of this chapter, some possible future work is presented.

6.1. Discussion: Process reflections

As suggested in [52]: “dealing with a design task in an unknown or only partially know situation, with demanding and stressed clients and users, with insufficient information, with new technology and new materials, with limited time and resources, with limited knowledge and skill, and with inappropriate tools, is a common situation for any designer”. Stolterman [52] reflects really well some of the conditions within our design process. In this concrete project, we had the following elements:

- A partially known situation:
  1. Old people’s behaviour: will NAO be accepted?
  2. Unknown movement design: even when a brief description of the movements was available, it was difficult to imagine them in the real world and it would be even more difficult to imagine the elderly’s mistakes while executing them.

- A demanding user:
  1. The time for the physiotherapy sessions is limited as well as the inpatients’ patience. In addition, their physical condition could constrain the time they can be waiting until the system is ready.

- A new technology:
  1. It was the first time programming both a robot and Kinect.

These elements conform a changing design environment, in which the requirements are refined as we go along the design process. Therefore, as explained in [52] and [53], the designer has to face plenty of situations where decisions based on their own skills and criteria will determine the next step. As a result of this, the system would evolve as the designer acquired more and more knowledge from the different technologies and scenarios. For instance, when we started programming NAO, the movements were rougher due to our lack of experience with this technology. Another example could be how the knowledge acquired about the elderly (how they move, what they demand and so on), made us have a better understanding on how the system should be.
6.2. Guidelines

A result of this project, a set of guidelines is presented. These guidelines are divided into three main groups: designing a model for geriatric physiotherapy interventions, Kinect recognition, and physiotherapist’s considerations and others.

6.2.1. Designing a model for geriatric physiotherapy interventions

It is important not to disturb the physiotherapist when a patient has already started a movement. Anything that does not belong to the physiotherapy is seen as a distraction. Still, there is no problem for them to have to control the system to begin or finish the session. Therefore, several recommendations are suggested below:

- Infinite repetitions for modelling.
  According to our physiotherapist, the inpatients always need a continuous visual stimulus. Therefore, if the modelling is interrupted, they will probably stop. At the same time, it is important not to have a specified number of repetitions. This can provoke the physiotherapist to trigger the same movement multiple times, and therefore interrupt the session. By keeping infinite number of repetitions during the modelling, the physiotherapist can correct the inpatients, explain a movement, without worrying about whether the model will stop.

  Moreover, by keeping infinite repetitions of the movement, the physiotherapist is only required for starting and stopping the movements. Therefore, we reduce the extra task associated to our system. In essence, once the movement has started nothing should require the physiotherapist’s attention except the inpatients.

- A three-dimensional model interface is better than a screen-based model interface.
  Especially for tricky or complicated movements, a three-dimensional model of the movements makes it easier for the inpatients. They seem to understand the movements sooner and execute them more precisely.

- The modelling of movements must be exaggerated.
  When possible, the model should try to exaggerate the movements. We have seen how narrow movements of the model have caused some inpatients to decrease their angular movements or reach less far than they would normally do.

- The model should be the one initiating the movements.
  First the model starts. Following the model, the elderly mimic it. If this order is kept, it is easier to get the elderly synchronized with the model, and therefore, encourage them to explore their limits. As showed during the second workshop (see Section 5.5.2), the synchronization is lost when the inpatients, instead of the system, start performing the movements.

- The system must be adjustable: movement speed and limitations.
  As described in [20], the possibility of adjusting the system to each user is primitordial. In order to develop a final product, it must be adjustable and able to recognise the user’s errors perfectly and take their limitations into the formula. In fact, some users are better than others doing some movements, so this must be reflected on their personalization of the system. If the system is too slow compared to the user, the synchronization between them will be lost [13].

  The ideal situation would be one where the system learned from the user. It would know what type of limitations each user had only by watching them a few times. This is only applicable to the error recognition, and it does not affect the modelling.

- The movements must allow the possibility of being paused during their execution.
  One of the main concerns of the physiotherapist is the possibility of pausing the robot while he needs to explain something to the inpatient.
6.2. GUIDELINES  CHAPTER 6. DISCUSSION, DESIGN CONCLUSIONS AND FUTURE WORK

- Realism of the movement and in-situ corrections.

Because of the inpatients’ special conditions, it is difficult to imagine how they will perform the movements. Thus, attending a rehabilitation intervention before designing the movements is strongly recommended. If it is not possible (as it occurred in this project), it is recommended to spend some hours testing and improving the design with a final user.

- Triggering of wrong movements.

There are at the most two wrong movements associated to each right one. In consequence, this simplifies the evaluation task. The programmer just needs to check some specific parameters, ignoring the rest. For instance, when the user is doing an abduction of shoulder, our main concern might be their elbow’s position. If the elbow is located 20 centimetres in front of their shoulder, it is considered a wrong execution. We do not need to care about the rest of their joints.

6.2.2. Kinect recognition

By using Kinect as a device to track the users’ skeleton, the designer must consider the following:

- The programmer should check that the Kinect version used recognizes people in wheelchairs. Some frameworks work with previous versions of Kinect where this feature is not yet implemented. In fact, the problem is not the wheelchair itself, but any armchair.

- By using Kinect within one-to-one interventions, the researcher must programme it to recognise only the user and not the physiotherapist. This could be done by activating the most active player option, which is included into Kinect’s SDK. This will avoid tracking wrong movements caused by the physiotherapist in case they entered the scene.

- It is preferable to place Kinect at a two meters height, facing the inpatients. This will reduce the possibility of losing view of the inpatient’s skeleton if the physiotherapist crosses the scene and blocks Kinect.

- When two skeletons are being tracked at the same time, there is the possibility of disconnecting the skeleton analysis. This situation occurs when the physiotherapist moves a person in order to correct them. Such situation could confuse Kinect since two skeletons are in contact. Once the second skeleton disappears, the tracking analysis may be activated again.

- Kinect’s SDK includes a “seating” option. The elderly are usually seated while performing arm movements. Consequently, this option could be activated.

- In order to recognise a valid movement, it is only needed to check whether the inpatient performs a determined angle or pose, and not the complete gesture. For example, during an abduction of shoulder modelling, it is not necessary to check if the inpatient reaches the challenged position (creating a 180 degrees angle), but the minimum accepted angle (90 degrees) for that movement.

- The same approach is followed for wrong movements. They would be launched whenever an inpatient reaches a determined position. Coming back to the abduction of shoulder example, whenever the inpatient’s elbow is located 20 centimetres in front of their shoulder, it is considered a wrong execution, regardless of any other body part.

6.2.3. Physiotherapist’s considerations and others

- It is complicated not to add an extra control task to the physiotherapist. In order to reduce this overload, speech recognition could be used to control the system. In essence, the speech system must launch and stop either right or wrong movements. This way, the physiotherapist could remain involved in the action and keep their attention on the inpatients. If a speech system is not used, the following points should be considered:
There are two main states within the rehabilitation interventions: a relax state, when the inpatient is not making any movement, or an active state, when the modelling has already started.

When the therapy is on an “active state”, the physiotherapist should not be interrupted by anything that is not the inpatient. If the designer wants to provide some feedback to the physiotherapist, this should be placed as close as possible to the inpatient. According to our physiotherapist, the best solution consists in placing it directly on the inpatient.

While the therapy is on a “relax state”; the designer is free to interrupt the physiotherapist as long as this interruption does not break the session’s dynamic. The physiotherapist can, for example, trigger a movement when the therapy is under this state.

If a laptop or similar device is used, it should be used only to launch or stop the action, and never to give feedback during the movement. The physiotherapist will not look at the screen once the modelling has started.

Keeping a manual interface to force the control of the system is recommended in the event of technology failure.

In order to reinforce the relationship between physiotherapist and inpatients, these should think that the corrections are done by the system even if this is not true (and the physiotherapist is the one who actually is evaluating them by using the system). In this way, they would think: “a machine has decided it and a machine never fails, so it must be me who has done something wrong”.

6.3. Conclusions

In this project, NAO and Kinect create a new system to support the physiotherapist during their one-to-one intervention with the elderly. In addition, a comparison between a physical and a virtual model representation for the movements proposed is put into practice. This comparison is aimed at testing which model is more beneficial for the elderly. As a result of this conclusion, the physical version of NAO (PhyNAO) contributed more to improving the quality of the therapy than the virtual version (ViNAO). As an example of this, we can observe (see Section 4.3.5) that the number of times the physiotherapist needed to move a inpatient were less under PhyNAO condition than under ViNAO condition.

6.4. Future work

This section analyses and formulates future improvements that could be done to our system. Those upgrades are doomed to continue using an external model, but try to solve some of the problems from the second iteration or to improve the social aspect of the therapy.

There are some ongoing projects that try to engage the users by knowing their feelings [29] [14] or recognising them when they enter to a place [22]. By incorporating the aspects aforementioned to our sessions with elderly, a relationship could be built between the inpatients and the robot. This way, the robot would not be seen only as an implacable judge who evaluates their movements, and a possible rejection towards the robot could be avoided.

Another possible improvement consists in removing the hardware limitations of the model (see Section 4.1.4). The model would be able to perform any movement since those limitations are removed.

Two proposals have been considered to avoid losing view of the inpatient’s skeleton when the physiotherapist crosses Kinect’s visual range. The first one consists in changing Kinect’s position, and the second one consists in adding another Kinect. This problem would be solved by changing Kinect’s position from in front of the inpatient to above the inpatient. Furthermore, incorporating another Kinect, not only would solve the problem, but could improve the accuracy of the system. If the precision of the system is robust enough, it could be used to capture other clinical data.

Nevertheless, the functionality that could most improve the system is a speech recognition control. Incorporating speech recognition, the physiotherapist could trigger a movement, activate/deactivate Kinect and stop the movement modelling. This would reduce the extra controlling task added to the physiotherapist during this project.
Finally, the major future point of investigation may be how to provide feedback to the physiotherapist. As we have seen before, where and how are the main issues to be solved while supporting the physiotherapist with information during the active part of the intervention.
Bibliography


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BIBLIOGRAPHY


Appendix A

Physiotherapy Requirements

Luis Marquez Segura, physiotherapist
Date: 28th September 2012
To: Elena Marquez Segura / David Lopez Recio
Location: Mobile Life @ SICS, Kista, Sweden

Specification of movements for the physiotherapy interventions and the most common inadequate appropriation of such movements that the inpatients perform

**Flexion of shoulders**, "from 0 to 90 degrees – "arms moving forwards:

- Initial position: arms relaxed close to the body, palms touching the body.
- Final position: arms straight, in front of the body, forming 90 degrees with respect to the torso (hands aligned with the shoulders), palm facing down.
- Typical Inadequate Appropriation: Cervical and dorsal (spine) extension, i.e. the inpatients tend to lean backwards (neck and back).

**Abduction of shoulders**, from 0 to 180 degrees – "Separating the arms from the body":

- Initial position: arms relaxed close to the body, palms touching the body.
- Intermediate position: arms straight to the side of the body, forming 90 degrees with respect to the torso (arms parallel to the floor), palms facing down.
- Final position: arms straight up, forming 180 degrees on the side above the head.
- Typical Inadequate Appropriation: the inpatients tend to combine this movement with some degree of flexion of the shoulder, i.e. instead of moving the arms to the side of the body, they move them up and forwards the body.

**Extension of shoulder**, from 0 to 45 degrees – "Arms moving backwards":

- Initial position: arms relaxed close to the body, palms touching the body.
- Final position: arms straight to the back of the body, forming 45 degrees with respect to the torso of the body, palms facing inwards.
- Typical Inadequate Appropriation: Cervical and dorsal (spine) flexion, i.e. leaning forwards.

**Flexion of arms**, from 0 to 160 degrees – "Bending the arms like in weight training":

- Initial position: arms relaxed close to the body with palms forwards.
- Final position: arms bended with palms touching the shoulders.
- Typical Inadequate Appropriation: the inpatients tend to separate arms from the body (add some abduction of shoulders).

**Pronation and supination** – "Turning the palms":

- Initial position: Arms relaxed close to the body with palms forwards.
- Final position: Arms relaxed close to the body with palms backwards.
APPENDIX A. PHYSIOTHERAPY REQUIREMENTS

Typical Inadequate Appropriation: None.

**Open and close hands** (emphasis in opening):
Initial and final position of the arms: The most comfortable position for the inpatient
Typical Inadequate Appropriation: None.

**Flexion of knees**, from 0 to 90 degrees – "Smacking the backside":
There are two options, sitting down on a chair or standing up (preferably the second one). For the latter, the initial position is standing upright with both feet on the ground.
Final position: one knee is flexed, with the foot going to the back of the body (as if it would touch the backside of the inpatient)
Typical Inadequate Appropriation: the impatient tend to combine this movement with flexion of hip (leg moving forwards).

**Flexion of hip**, from 0 to 100 degrees – "Like in military service":
There are two options, sitting on a chair, and standing up (preferably the second one). For the latter, the initial position is standing upright with both feet on the ground (like in "flexion of the knees").
Final position: knees moving up a bit above the level of the hip; the shin/calf lie parallel to the torso (knees flexed).
Typical Inadequate Appropriation: the inpatients tend to combine/confuse with flexion of the knees (sometimes they do more the latter than flexion of the hip).

**Extension of hip**, from 0 to 45 degrees – "Move the leg backwards":
Initial position: Standing up with both feet on the floor.
Final position: Standing up on one foot; the other leg straight backwards up to 45 degrees with respect to the torso.
Typical Inadequate Appropriation: the impatient tend to combine/confuse with abduction of hip.

**Abduction of hip**, from 0 to 60 degrees – "Separate the leg from the body":
Initial position: Standing up with both feet on the floor.
Final position: Standing up with only one foot on the floor and the other leg straight towards one side up to 60 degrees with respect to the torso.
Typical Inadequate Appropriation: the impatient use to combine/confuse with extension or flexion of hip.
class MyClass(GeneratedClass):

def __init__(self):
    GeneratedClass.__init__(self)

def onLoad(self):
    self.ok = [False]*3

def onUnload(self):
    #puts code for box cleanup here

def onStart(self, nInput):
    self.ok[nInput-1] = True
    if( self.ok[0] and self.ok[1] ):
        self.ok[0] = False
        self.ok[1] = False
        self.signal_front()
    elif (self.ok[0] and self.ok[2]):
        self.ok[0] = False
        self.ok[2] = False
        self.signal_back()
    elif (self.ok[0]==True):
        self.ok[0] = False
        self.no_signal()

def onInput_signal1(self):
    self.onStart(1)

def onInput_signal2(self):
    self.onStart(2)

def onInput_signal3(self):
    self.onStart(3)
Appendix C

Interviews

C.1. NAO acceptance

1. What do you think about this robot?

2. Do you think the robot’s movements are natural?
   □ Yes
   □ No

3. Do you know which movement you must execute when you are watching the robot?
   □ Yes
   □ No

4. Do you consider the robot could do some movements that you cannot?
   □ Yes
   □ No
   a) Which ones?
   b) Do you think it is because of your limitations or because the robot moves better than a normal person?

5. Why do you think the robot does wrong movements?

6. Would you like the robot to stay here or do you prefer the video?
   □ Robot
   □ Video
   a) Why?

7. What do you think about the robot?
   a) Is it a useful tool or a toy?
   b) Does it look funny or stupid?
C.2. Comparative between systems

1. When do you think it is easier to make the exercises?
   - □ Alone with the physiotherapist
   - □ With the physiotherapist + robot
   - □ With the physiotherapist + video

2. Which system do you like the most?
   - □ Alone with the physiotherapist
   - □ With the physiotherapist + robot
   - □ With the physiotherapist + video

3. When do you understand the movements better?
   - □ Alone with the physiotherapist
   - □ With the physiotherapist + robot
   - □ With the physiotherapist + video

4. When do you understand the wrong movements better?
   - □ Alone with the physiotherapist
   - □ With the physiotherapist + robot
   - □ With the physiotherapist + video
Appendix D

Demographic study

1. Name:
2. Age:
3. Do you exercise besides physiotherapy?
   □ Yes
   a) How long do you exercise?
   b) What type of exercise do you do?
   □ No
4. Do you watch the TV?
   □ Yes
   a) How long do you watch it?
   b) What type of programs do you watch?
   □ No
5. Do you watch any TV program in which you must follow some instructions? (cooking programs, gymnastics, etc)
   □ Yes
   a) Which one?
   b) Do you think they could be improved?
      • Yes. How?
      • No
   □ No
6. Do you know what a video game is?
   □ Yes
   a) Which ones do you know?
   □ No
7. Have you ever played any video game?
   □ Yes
   a) How often do you play?
   b) What do you usually play? (computer / video game console / others)
   □ No
8. Have you ever seen a robot?
   □ Yes
   a) Which one?
   □ No

9. What is your opinion about robots?