Interactive Ergonomic Analysis of a Physically Disabled Person's Workplace

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Abstract. This paper presents a new gesture based approach for interactive ergonomics evaluation, and especially adaptation of physically disabled people's workplaces. After a general survey of existing tools, we describe the requirements to perform ergonomic analysis for disabled persons by using a virtual reality approach. We specifically propose a framework unifying the synthesis and the analysis of a virtual human's motions during a working task. We finally present the current status of this study and future works.

Introduction

Design of virtual environments for ergonomics has gained considerable research interest in recent years. Many tools have been developed to perform ergonomic analysis in a virtual environment [2], for example: Jack [1], SAMMIE [7], MANERCOS [5], SAFEWORK [10], Delmia [3] and RAMSIS [8].

Those tools are commonly used by designers to perform occupational ergonomic analysis on a virtual mock-up, by immersing a virtual human controlled by direct or inverse kinematics. Within the above applications, the humans models cover about 90% of the population, but other humans with extra specificities are unfortunately excluded, especially physically disabled persons.

A new tendency aims to provide databases [7] covering an even wider range of population including persons with disabilities. Each record of such database contains information concerning anthropometry, joints limits, common postures and task specific behaviors for a singular person. Those data allow to display the problems that each recorded individual is predicted to experience.

However, recorded behaviors cannot easily be extrapolated to new task or custom individual. We present here a preliminary work which aims to overpass those restrictions.

This paper is organized as follows: the first section describes the requirements to perform ergonomic analysis for disabled persons using virtual reality. The next section presents a motion controller dedicated to ergonomic analysis for virtual disabled people. The last section concludes by presenting the current status of this study and the remaining challenges for future work.

1 Performing ergonomic analysis for disabled persons

To perform ergonomic analysis, the first step consists in providing a description able to express relevant ergonomic aspects of the environment. While many of the existing tools are integrated in Computer Assisted Design softwares and rely on accurate and complex geometric models, our workplace description only focuses on the functional view using a gesture based representation. In order to specify possible gestural interactions of the virtual human with its workplace, we use the Smart Object representation proposed by Kallmann [6], where each object encapsulates all the necessary information to describe how to interact with it. Finally, to ease the manipulation of the objects, and the retrieval of dynamic information such as torques or forces, a physically based simulator has been employed.

The next step concerns the integration of the virtual human in the environment. When creating virtual humans, there are varying notions of *virtual fidelity*, depending on the application [1]. Interactive ergonomics necessitates to integrate various information such as anthropometric data, functional ability, admissible joint angles, maximum strengths, but also physiological data like recovery time or fatigability. We choose to model disabilities as a set of specific constraints altering the synthesized motion. As the effects resulting from a specific disease are more useful for us than the disorder itself, we assume that theses constraints can be defined as a set of simple or combined effects expressed from the anthropometry (ex: broken arm), from physiological features (ex: strength limits) or trajectory fluctuations (ex: trembling, inaccurate pointing).

Ergonomic analysis can usually be performed at three main levels: the task level, the postural level and the dynamical level. At the task level, empirical laws permit to evaluate the ergonomics of a specific task from preliminary information without any simulation process. For example revisited NIOSH equation [11] are used to evaluate a lifting task from only two parameters : the initial posture and the lifted load. The occupational level requires a postural or a motion simulation process to analyze the successive poses of the human during a specific task. Reach area, accessibility or field of vision analysis are part of the tests that can be performed here. The dynamical level deals with the forces and torques implied by the motion. Physiological analysis can then compute the impact of the motion on the human, for example fatigue by using a joint-level model [9].

The next section describes how disabilities are included in our framework where the three analysis levels are integrated.

2 Motion control and ergonomic analysis

We present an analysis-synthesis framework (Fig 1) which allows to synthesize motor tasks from physical information while providing ergonomic relevant information at each of the last three levels.

In this framework, the virtual human's physical information are represented as a set of constraints to the motion, divided in three categories: global task

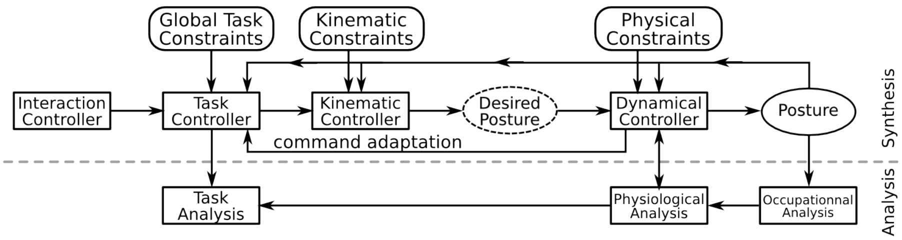

Fig. 1. The analysis-synthesis framework

constraints, kinematic constraints and physical constraints. The next paragraph describes, with an example, how those constraints are used to synthesize a motion relevant for ergonomic analysis.

Each selected interaction (*push a box*) is expressed as new goal for the task controller. Respecting global task constraints (*hand already used, broken arm*), the task controller plans a motor program as an ordered set of motor commands applied on the effectors space. The kinematic controller then computes the corresponding desired posture according to specific kinematic constraints (*reduced degree of freedom, angular limits, inaccuracy*). The dynamical controller then uses this posture, jointly with physical constraints (*collisions, strength limits*), to compute the motion. To obtain the final gesture, this process is repeated until the commands are satisfied.

In reaction to physical interactions (*collisions, high torques*) blocking the motion, the task controller may revise its control strategy by proposing another sequence of motor commands, as would a real person do to accommodate, thus over-passing their disability.

Using the framework, informations required to perform ergonomic analysis are available: task informations thought the motion controller, postures and dynamics as outputs of the dynamical controller.

3 Current work

We have developed a physical environment by integrating an existing dynamic simulator supported by a virtual reality platform called ARéVI. Simple environments, responding to physics, can already be defined using simple geometrical primitives. We are currently working to enhance the objects description using the Smart Object framework.

A virtual human prototype, capable of pointing objects, as also been implemented using the Sensori-Motor Model described in [4]. The simple motion primitives will be combined for simulating more complex tasks.

Conclusion

This paper aims to present our preliminary work on a framework for ergonomic analysis of a disabled person's workplace. We presented the 3 main requirements to perform ergonomic analysis: a gesture based description of the workplace, a virtual environment using dynamics and the modeling of disabilities as motion constraints. Based on those essentials, we finally propose a framework permitting the generation of accurate motion and ergonomic analysis at different levels.

Our perspectives are to concretize our framework and confront it to a use case provided by ergonomists. We are planning to apply the framework to the Sensori-Motor Model which respects natural control laws. Having a constraint compliant model, we will experiment our gesture based approach to model disabilities. Finally, we will evaluate our model using a real case study provided by experts in ergonomy.

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