Analysis of human navigation and manipulation motions

A. Egges
Center for Advanced Gaming and Simulation, Utrecht University, Utrecht, the Netherlands, egges@cs.uu.nl

Introduction

Over the last few decades a lot of research has been done in the field of human motion analysis. A very well-known technique used for motion analysis experiments is the point-light display [3]. Although the point-light display has been a viable tool for such types of experiments, more modern technology, such as a motion capture system, can be used to record human motion in a much more precise manner. There are many advantages to using a motion capture system for motion analysis experiments:

- The recorded data is a precise 3D representation of human joint motions
- No additional video analysis tools are required for retrieving the data
- A motion capture suit with optical markers does not inhibit natural motion
- Recorded motions can be easily visualized on 3D characters

At Utrecht University, we are involved in a variety of motion analysis experiments. One of the most important goals of these experiments is studying combined navigation and manipulation actions, an area of research that is still quite unexplored. Examples of such combined actions are walking to a door and opening it, or walking past a table while picking up an object from it. Our final objective is to define a model that can predict such kinds of combined actions. Recent studies show that very specific motions in the industrial domain can be predicted by a model with a certainty of 90 percent [4]. Although these results are an exception in the study of human motion it also shows that if one have enough information about the subject and the task the subject will perform, one can predict motion. Other remarkable results are shown in recent work by Arechavaleta et al [1,2]. One of their conclusions was that the path humans take to reach a certain goal can be predicted by a clothoid curve, also known as a Curnu spiral, for about 90 percent of the studied takes. Another remarkable result was that the trunk can be described as the 'steering wheel' of human locomotion.

The goal of the research shown in this presentation is to find out whether the results from these previous experiments still hold when applied to combined navigation and manipulation actions. As a test case for this research, we have analyzed the motion of several subjects walking toward a door and opening it (see Figure 1).

Experiment setup

We selected a group of ten subjects (five female, five male) for our experiments. Of the ten there were five left-handed and five right-handed subjects. With each of the subjects, four experiments were done. In the first two experiments, a subject had to move towards the door and open it as if someone rang the doorbell. These experiments were taken from five different start positions. The second experiment differed from the first in the sense that a subject carried a coffee cup in their preferred hand. In the third and fourth experiment the subjects not only walked to the door and opened it, they also passed through it, going in three different directions afterwards. In the first three experiments the door opened towards the subject with the door-latch on the right side. In the last experiment the door-latch was on the left side and the door opened outwards.

Figure 1. *The motion capture lab with the door located in the center.*

Using the results of these experiments, we address five main research questions:

- What is the 'steering wheel' of the human body in case a combined motion action is performed?
- Is the approaching path predictable in a setup of navigation and manipulation?
- When do subjects use the left of right hand to open the door?
- Is the approaching speed influenced by gender, handedness, approaching direction, the direction in which the door opens or the direction in which the subjects leave after walking through the door?
- Is the distance and position relative to the door while opening it influenced by gender, handedness or approaching direction?
- Is the distance to the door while opening it influenced by gender, handedness or approaching direction?

Results

One of the first questions we studied was the steering wheel principle. We investigated whether the trunk is really the steering wheel and whether this still holds in combined navigation/manipulation actions. Our results confirm that the trunk is indeed the steering wheel while navigating. However, this changes as soon as a manipulation action is performed. During manipulation tasks, the upper body of the subject becomes involved in the manipulation action, and thus the trunk can no longer be used as the steering wheel. Additionally, more complicated navigation actions are performed at the same time, such as side-stepping or moving backward. In these cases the relation between the direction of movement and the direction the body parts are facing is lost.

We also analyzed the average distance of the subject to the door while opening it. Our analysis shows that there was no significant relation between the distance to the door and the gender. We have also looked at the role of different body parts used to cover this distance (legs, trunk and arms). Although more thorough analysis is required, the pose seemed to be very different per gender and handedness. Actually, in a few cases the subjects leaned backwards while opening the door.

We are currently in the process of further analyzing the data. During the presentation, a more extensive outline will be given of the results of the analysis and how this translates to the research questions that were formulated in the previous section.

References

1. G. Arechavaleta, J-P. Laumond, H. Hicheur, and A. Berthoz. Optimizing principles underlying the shape of trajectories in goal oriented locomotion for humans. *In IEEE-RAS International Conference on Humanoid Robots.* Genova (Italy), 2006.
2. G. Arechavaleta, J-P. Laumond, H. Hicheur, and A. Berthoz. The nonholonomic nature of human locomotion: a modeling study. Pisa (Italy), 2006. *IEEE / RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics.*
3. L.T. Kozlowski and J.E. Cutting. Recognizing the sex of a walker from a dynamic point-light display. *Perception and Psychophysics*, 21:575–580, 1977.
4. David W. Wagner, Mathew P. Reed, and Don B. Chaffin. Predicting foot positions for manual materials handling tasks. Presented at SAE Digital Human Conference, Iowa City, Iowa, 2005.