DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

A Metric for Hand Comfort/Discomfort Evaluation: Towards Expressivity in Spatial Control

Jonas Mayer

DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

A Metric for Hand Comfort/Discomfort Evaluation: Towards Expressivity in Spatial Control

Eine Metrik zur Comfort- und Discomfortevaluation der Hand: Hin zur Aussagekraft räumlicher Steuerung

Author:	Jonas Mayer
Supervisor:	Dr. Nicholas Katzakis
Advisor:	Prof. Gudrun Klinker
Submission Date:	Submission date

I confirm that this bachelor's thesis in informatics: games engineering is my own work and I have documented all sources and material used.

Munich, Submission date Jonas Mayer

Acknowledgments

Abstract

Contents

1 Introduction

1.1 Motivation

Over the last two decades human-computer interaction in desktop computer environments has evolved .... resulting in the keyboard-mouse input standard. Using a WIMP interface and multiple keyboard macros users can complete a variety of tasks efficiently and effectively. However, in interaction contexts such as virtual reality and human-robot interaction which become more and more relevant, traditional interaction techniques are not a suitable solution. Speech is an intuitive way of interacting, even though it by nature requires the user to talk constantly which is not optimal for longer periods of time. Additionally, speech interaction is limited when it comes to contexts such as commanding a robot to execute different household tasks or playing a real-time strategy game in virtual reality, where spacial navigation is important. In such cases, pointing with hands is a much more efficient and intuitive solution. By using different hand postures different commands can be issued, which enhances interaction expressiveness similarly to key macros in a traditional environment. The main challenge for hand postures has been fighting physical forces that cause different symptoms like fatigue or discomfort. The latter are generally known to limit user experience and precision [**short1999precision**] in the task environment.

When designers create a hand posture interaction environment, they have to take these physical factors and hand posture comfort and discomfort into account. One goal is to choose an optimal set of hand postures that will ensure maximum task performance and comfort for the user while creating a minimum of discomfort. Especially for larger sets of commands that becomes challenging as there are no straight forward metrics that allows to compare hand postures quickly [**naddeo2015proposal**]. So either a costly user study has to be organized to get objective feedback, or the designers have to rely on their own subjective impressions and assumptions.

Therefore, the main goal of this bachelor thesis is to support the creation and evaluation of a hand posture vocabulary for efficient pointing-based posture interaction.

1.2 Study Goals

The approach taken to solve the problem stated above, is based on the hypothesis that hand posture comfort and discomfort do affect the users performance in a specific task and obviously the user experience. Based on this, two main goals were formulated.

1.2.1 Create a Metric for Hand Posture Comfort/Discomfort

The objective was to create a metric, that allows designers to get a quick and objective evaluation of a hand posture regarding Comfort and Discomfort. The metric should be used to compare similar hand postures and to rule out bad ones directly.

For the creation of the metric state of the art comfort and discomfort models were taken into consideration. Looking at the human hand's complex anatomy, multiple influential factors for hand posture comfort and discomfort were identified. In order to compute a concrete metric value in real time, the identified factors were implemented in a Unity 3D environment. Finally the metrics correctness was verified in a user study.

1.2.2 Show the Metric's Influence on User Performance

While the correlation of Comfort/Discomfort and user experience is rather trivial, the influence of Comfort/Discomfort on user performance was only indicated for specific different contexts. Therefore the objective was to show this correlation in the context of hand posture comfort/discomfort as measured by the metric. This was also targeted in a user study.

This bachelor thesis aims to support the creation and evaluation of a hand posture vocabulary for efficient pointing-based posture interaction. For that we propose a hand posture comfort/discomfort metric that allows for quick and objective hand posture evaluation. We combined state of the art comfort/discomfort models with current hand anatomy and ergonomics knowledge to create models that can predict hand comfort and discomfort given a specific posture. Based on our model we created a naive metric, which we improved in a second step using data from a user study. Finally another user study was used to validate our metric and to show the impact of comfort and discomfort on performance in a hand pointing task.

2 Related Work

2.1 Nikolas Schneider

Being its follow-up work, this Bachelor Thesis was highly influenced by the work of Nikolas Schneider. In his Bachelor Thesis Nikolas Schneider compared three different hand postures, namely a pointing, spiderman and a pinching posture in terms of precision and performance in a 3D-pointing task.

For that, he conducted a user study, where the participants had to perform a target shooting test in a Unity 3D environment using one of the mentioned postures. For that purpose the participants wore an AR-Rift giving them augmentations of the targets to shoot and the shooting direction, indicated by a laser beam. The beam's origin and direction were computed differently for each hand posture. In order to track the participant's hand, a metal construction featuring a Leap hand tracker and ART marker was strapped to the forearm. Applying a KNN algorithm on the data gained from the Leap, the user's hand posture was determined in order to make sure, the participant would hold the posture throughout the test. Right after the target shooting, users were asked to rate their experience with the hand postures regarding perceived accuracy and comfort.

The results showed that generally the pointing posture performed best, followed by the spiderman posture and finally the pinching posture. The questionnaire revealed similar results for user perception, indicating a connection between user comfort and performance.

2.2 Comfort and Discomfort

As the main goal was to create a quantitative metric for hand posture comfort and discomfort evaluation, it was crucial to understand state of the art concepts of comfort and discomfort and to have a look at similar approaches taken to create comfort metrics.

In their editorial Vink et al. [**vink2012editorial**] give a good overview over current comfort and discomfort definitions, different models explaining the origin of both. They state that even though there has been much research on comfort and discomfort, the results are generally ignored in practical design contexts due to their broad theoretical scope. Concluding they express the importance of further research in order to generate applicable models and metrics for concrete body parts.

Fagarasanu et al. [**fagarasanu2004measurement**] discovered that limbs in neutral postures showed a significantly lower muscle activity, indicating higher perceived comfort. Apostolico et al. [**apostolico2014postural**] defined the term "Range of Rest Posture" (RRP), a angular range for articular joints where the joint can be seen as statistically in rest. They further measure the RRP for multiple human joints and express its importance for evaluation of postural comfort. Based on this Naddeo et al. [**naddeo2015proposal**] used a neural network to generate a concrete metric for postural comfort based on RRP. Therefore they compare user comfort ratings of certain joint postures with the measured distance to the RRP. They further also described other potential influential factors to take into account when evaluating comfort.

Short et al. [**short1999precision**] conducted a user study to investigate the so called precision hypothesis. The results indicated that generally more comfortable posture generate a higher precision in pointing tasks. This effect is magnified, when the targets become smaller.

subfig

3 Theoretical Foundation

3.1 Comfort and Discomfort Definitions

Before actually creating a metric, it is obviously crucial to have an exact definition of the terms comfort and discomfort. In this bachelor thesis comfort and discomfort will be referred to as described by Vink et al. [**vink2012editorial**].

In their paper comfort is defined as "pleasant state or relaxed feeling of a human being in reaction to its environment". Therefore comfort is a positive emotional state in reaction to the environment highly dependent on emotions and expectation. Comfort is generally related to "luxury, feeling relaxed or being refreshed".

Discomfort on the other hand is defined as "an unpleasant state of the human body in reaction to its physical environment". Physical stress is the main cause of discomfort, a negative state of the body. Discomfort is often felt in the form of fatigue, stiffness and pain and can in extreme cases even lead to injury.

It is important to keep in mind, that comfort and discomfort are in fact not two opposing sides on one scale. They much more are two independent factors influencing the overall well being in different ways, somewhat similar to Herzberg's motivation-hygiene theory. The absence of discomfort does not automatically result in comfort and vice versa.

An example for the importance of this differentiation can be found when choosing the softness of foams for mattresses or seats. While softer materials will continuously increase perceived comfort, having too soft foams will result in reduced postural support, leading to higher stress on muscles and tendons and finally causing discomfort symptoms like stiffness or back pain.

3.2 Hand Comfort and Discomfort Metric Components

Looking at the hand's anatomy the following four components were determined to be most influential on comfort and discomfort based on the definitions for above.

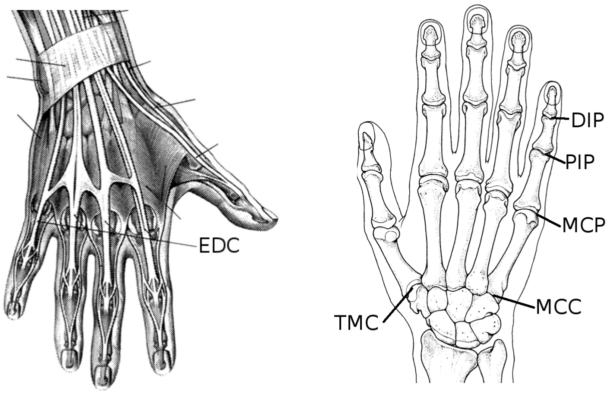

Figure 3.1: Hand Anatomy

3.2.1 Deviation from Range of Rest Posture

The **Range of Rest Posture (RRP)** component is based on the work of Apostolico et al. [**apostolico2014postural**]. They define the "Rest Posture" of a human joint as a posture, where involved muscles are completely relaxed or strain is minimized. When in Rest Posture, maximum comfort is perceived in that particular joint. Thus perceived comfort should decrease when deviating from the RRP. Due to anatomical differences between different humans, it makes more sense to look at the so called "Range of Rest Posture", a range of angles for an articular joint, where the joint "can be considered statistically in rest".

When looking at postures involving multiple joints, Naddeo et al. [**naddeo2015proposal**] state that comfort can be determined by combining the comfort values of the single joints.

In our case, we considered the human hand to have one RRP for each finger joint in a non-resting position with the palm facing downwards, resulting in a range of relaxed hand postures (Figure ???) , where the comfort is maximized. For a particular hand posture comfort can be computed by determining the angular distances to the RRP for every joint and adding them up.

3.2.2 The Inter Finger Angles

As it can be seen in Figure 3.1 the hand has a very compact and highly connected system of muscles, tendons and soft tissue that limits the individual movement of fingers. The fingers, excluding the thumb, share **most** of their flexor and extendor muscles. However minor individual flexion and extension of adjacent fingers is still possible due to finger tendons originating from different areas of the muscles. In the case of the *Extensor digitorum communis* (EDC in Figure 3.1) the finger tendons are even interconnected on the back of the hand.

In addition to this only three principal nerves serve the muscles of the hand, which makes it even harder for the motory system to fully differentiate between the individual fingers.

In conclusion of this, hand postures with high bending differences between the fingers should not only cause physical stress on both tendons and muscles, but also cognitive stress. This is due to the human trying to achieve and hold a complex posture with limited cognitive and physical means. This can lead to severe discomfort, which is manifested in cramping up the hand and pain.

3.2.3 Finger Hyperextension

3.2.4 Finger Abduction

3.3 Naive and Improved Metric

4 Implementation

4.1 Unity and the Leap

aa

4.2 Hand Model

aa

4.3 Hand Posture Detection

vsdv

4.4 Hand Posture Metrics

4.5 Random Hand Generator

4.6 User Study Tests

4.7 Problems

4.7.1 Leap Tracking

4.7.2 Hand Posture Detection

5 User Studies

5.1 First User Study

aa

5.2 Early Analysis and its Consequences

5.3 Second User Study

6 Results and Discussion

6.1 Results

aa

6.2 Discussion

List of Figures

List of Tables