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Bachelor of Science

Development of a Natural VR User Interface Using Haptic Gloves

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Dresden, August 19, 2020

Task Description

Write down your task...

Declaration of authorship

I hereby declare that I wrote this thesis on the subject

Development of a Natural VR User Interface Using Haptic Gloves

independently. I did not use any other aids, sources, figures or resources than those stated in the references. I clearly marked all passages that were taken from other sources and cited them correctly.

Furthermore I declare that – to my best knowledge – this work or parts of it have never before been submitted by me or somebody else at this or any other university.

Dresden, August 19, 2020

Lucas Waclawczyk

Kurzfassung

abstract text german

Abstract

abstract text english

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1 Introduction

2 Development

2.1 Devices and Setup

For the purpose of thesis, I used a pair of haptic gloves called Avatar VR which is a registered trademark of NeuroDigital Technologies, S. L., referred to as ND hereafter. The company's details can be found at `neurodigital.es`.

Additionally, a Vive tracker was used to determine the user's hand position and orientation. The Avatar VR can be mechanically connected to the tracker using a coupling, that needs to be acquired separately. The named devices and the way of coupling can be seen in figure 2.1.

2.2 Skeletal Hand Model for the Avatar VR Haptic Glove

2.2.1 Abstraction of the Human Hand Skeleton

The human hand can be roughly divided into the parts shown in figure 2.2a, i.e. the *metacarpals*, *proximal phalanges*, *intermedial phalanges*, and *distal phalanges*. A joint connecting a metacarpal to a proximal phalanx is called *metacarpophalangeal joint*, and followed by a *proximal interphalangeal joint* and a *distal interphalangeal joint*.

Even though the carpals (grey in figure 2.2a) are physiologically quite relevant for hand movement, they stay relatively fixed compared to the other bone sets, and can thus be omitted in our simplified model. In anatomical nomenclature, the thumb is composed of proximal phalanx and distal phalanx only and follows a metacarpal. However, this model assumes a missing metacarpal and existing intermedial phalanx instead which will be modelled by a 0-length metacarpal for uniformity reasons.

The Leap Motion API version 2.0^[lea] uses the abstraction described above and adds

- an "end" joint per finger (at the end of the distal phalanx)
- a joint diagonally across the palm from the metacarpophalangeal joint of the index
- a joint in the middle of the palm

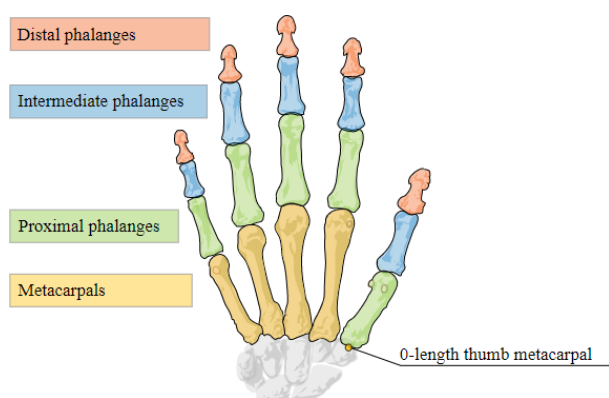


(a) Uncoupled devices, colors mark coupling point

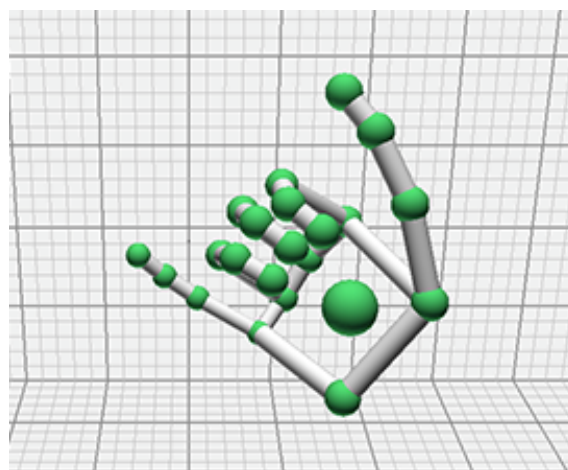


(b) Coupled devices on user hand

Figure 2.1: Devices used to track the user's hand: Vive tracker, coupling, Avatar VR



(a) General bone structure of the human hand



(b) Screenshot of an example hand representation in the Leap Motion API version 2.0, cropped

Figure 2.2: A model of the human hand; from [lea]

The most common representation includes cylinders for the bones and spheres for the joints. It is shown in figure 2.2b.

2.2.2 Technology and Function of the Avatar VR

To use the Avatar VR on a computer, one needs to download, install and run the ND Suite. This program provides a background service and GUI for managing and accessing the devices. A connection can be established via Bluetooth after which all sensor data is graphically accessible from the GUI.

The Avatar VR is equipped with three kinds of sensors:

- An *inertial measurement unit (IMU)* is located on the intermedial phalanx of each finger to measure its 3D rotation. The thumb is even equipped with two IMUs (one per phalanx) and the palm with an IMU that can measure both 3D orientation and 3D rotation. The "Motion" tab of ND Suite shown in figure 2.3a depicts the resulting orientations as orthonormal bases.
- At the locations marked in blue in figure 2.3b, the fabric is made of an electrically conductive material. These parts are used as contact sensors (short: contacts) to determine which of the marked locations are joined.
- The thumb also has a flex sensor, that will not be relevant for this thesis.

Furthermore, there are actuators at the locations marked in blue in figure 2.3c. These can be used for haptic feedback in a way that "[...] the brain perceives it as 'Real Touch' input", according to the producer.

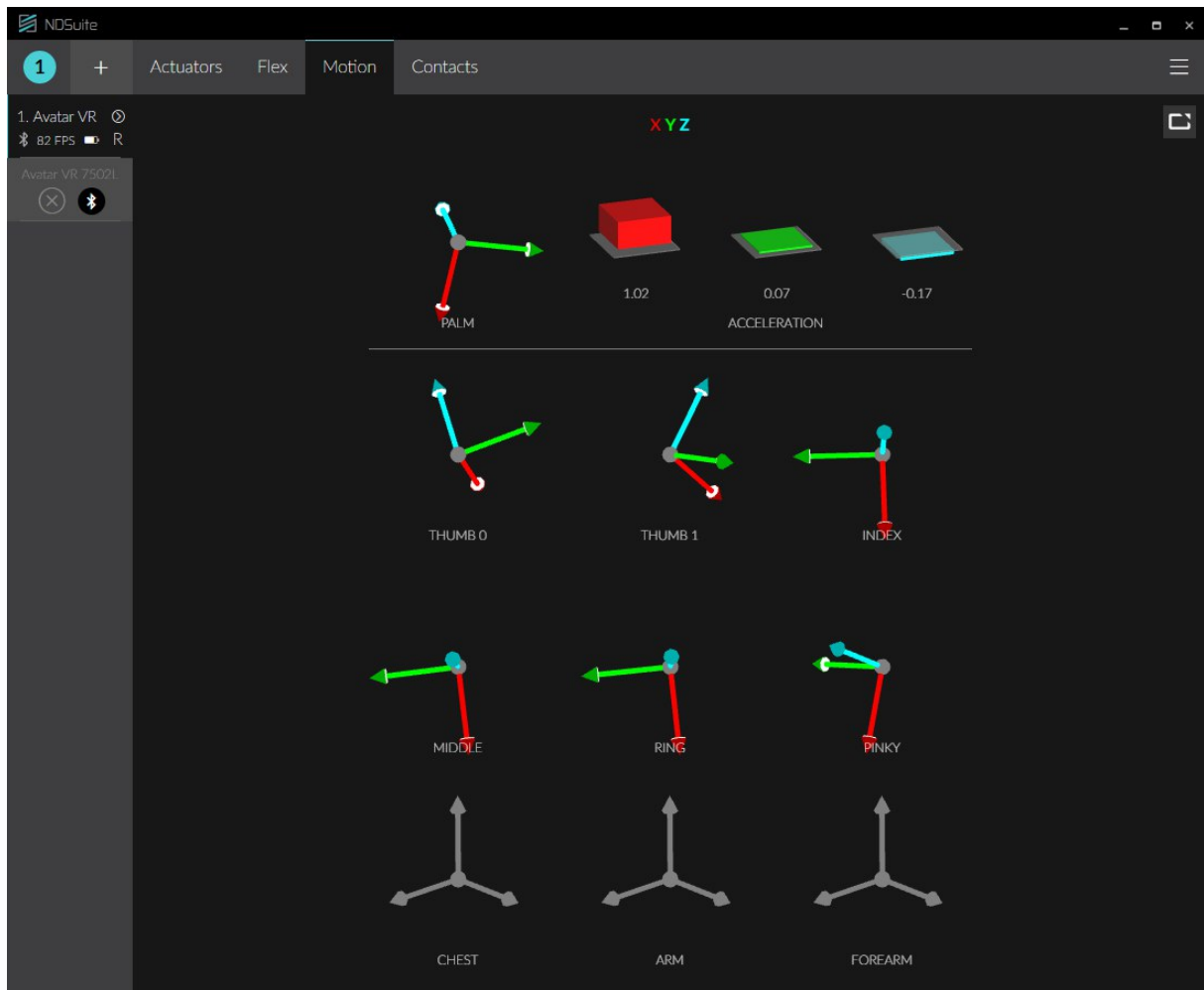
2.2.3 Using Data From the Avatar VR to Visualize the User's Hand

ND supplies a developer's API in the form of three files (`NDAPI.h`, `NDAPI_x64.lib` and `NDAPI_x64.dll` or `x86` respectively) which need to be included into the respective project in a suitable manner. A singleton of the `NDAPI.h` can be instantiated and used to access the data of devices connected to ND Suite in the form of quaternions for rotations and booleans for pairs of contacts.

The same model used by the Leap Motion API version 2.0 will also be used here. Leap captures absolute joint positions and optimizes them for visualization. In contrast, my approach for the Avatar VR is to use a fixed resting state geometry of the user's hand (bone lengths and resting state joint positions). At the time of a `draw()` command, the geometry is adjusted according to the data given by the glove and the Vive tracker.

The joint position data is managed by the following struct (only most important parts included):

```
struct joint_positions {
```



(a) "Motion" tab of ND Suite with orientations in an (optimistic) example hand pose



(b) Positions of contact sensors



(c) Positions of actuators

Figure 2.3: Sensors and actuators of the Avatar VR;
screenshots of ND Suite (b and c cropped)

```

// positions of hand joints in model space
// structure: hand_part<phalanx<position>>
vector<vector<vec3>> positions;
// positions linearized in hand_part major format
// set by make_array()
vector<vec3> linearized;
// correspondence of indices in linearized
// to double indices in positions
map<int, pair<int, int>> lin_to_anat;

// rotate complete part
void rotate(int part, quat rotation) {...}

// translate complete part along neg. z-axis
void translate_neg_z(int part, float z) {...}

// translate all positions
// used to move hand from construction origin
// to model view location
void translate(vec3 translation) {...}

// scale all positions
// used to realize hand size at construction origin
void scale(float scale) {...}

// generate linearized from positions
vector<vec3> make_array() {...}
};

```

First, the palm joints' resting positions are rotated according to the orientation given by the Vive tracker. The construction of each finger begins at the end joint of the distal phalanx which is translated along the negative z-axis by the hard-coded length of the distal phalanx and rotated by the respective quaternion (see below). The other phalanges are constructed in the same manner, before the whole finger is translated to the respective metacarpophalangeal joint. Finally, the whole hand is scaled to model view space and translated to the model view position of the Vive tracker.

Because the Avatar VR only returns one quaternion per finger (except for the thumb), I had to think of a way to distribute the orientation along all three phalanges

Glossary

distal interphalangeal joint joint connecting an intermedial phalanx to a distal phalanx. 2

distal phalanx finger bone farthest from the palm of the human hand, shown in figure 2.2a. 2, 4, 6

intermedial phalanx finger bone of the human hand between proximal phalanx and distal phalanx, shown in figure 2.2a. 2, 4

metacarpal set of bones in the palm of the human hand, shown in figure 2.2a. 2, 4

metacarpophalangeal joint joint connecting a metacarpal to a proximal phalanx. 2

proximal interphalangeal joint joint connecting a proximal phalanx to an intermedial phalanx. 2

proximal phalanx finger bone closest to the palm of the human hand, shown in figure 2.2a. 2, 4, 6

Bibliography

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[PGP⁺10] Philipp Pohlenz, Alexander Gräßle, Andreas Petersik, Norman [von Sternberg], Bernhard Pflesser, Andreas Pommert, Karl-Heinz Hähne, Ulf Tiede, Ingo Springer, and Max Heiland. Virtual dental surgery as a new educational tool in dental school. *Journal of Cranio-Maxillofacial Surgery*, 38(8):560 – 564, 2010.

Acknowledgments

I'd like to thank...

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