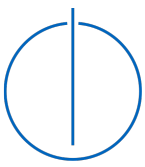
DEPARTMENT OF INFORMATICS

TECHNISCHE UNIVERSITÄT MÜNCHEN

Bachelor's Thesis in Informatics: Games Engineering

Smartphone-assisted Virtual Reality using Ubi-Interact

Michael Lohr



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Smartphone-assisted Virtual Reality using Ubi-Interact

Smartphone-gestützte Virtuelle Realität mit Ubi-Interact

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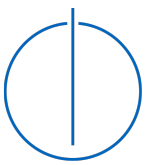

I confirm that this bachelor's thesis is my own work and I have documented all sources and material used.

Munich, October 15, 2019 Michael Lohr

Acknowledgments

Abstract

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Abbreviations

API Application Programming Interface

IMU Inertial Measurement Unit

JS JavaScript

UBII UBI-Interact

VR Virtual Reality

3D Three-dimensional

1 Introduction

Hi, this is my thesis, and I'm going to be the introduction.

2 Implementation

2.1 Ubi-Interact

UBI-Interact (UBII) is a framework for distributed applications, which enables to connect all kinds of different devices together. A centralized server is used to manage the system in a local network. It is currently developed and maintained by Sandro Weber, who is also the advisor for this thesis. The abstraction into devices, topics and interactions allows to decouple the implementation of a software from device specific environments.

2.1.1 Architecture

The main components of the UBII framework are:

Clients describe a basic network participant. For every client registered in the system, exists one network socket adress. So clients are an abstraction of a physical network device. They are defined by a unique identifier.

Devices can be registered by clients. A device is an abstraction for a virtual device, which groups different input and output devices together. It is defined by a unique identifier and a list of components.

Components contain the topic name, message format for input/output devices and wether it publishes input or receives output data. A data source for such an input device, could be any sensor for example a button or the camera. Data output examples for input devices are lamps and displays.

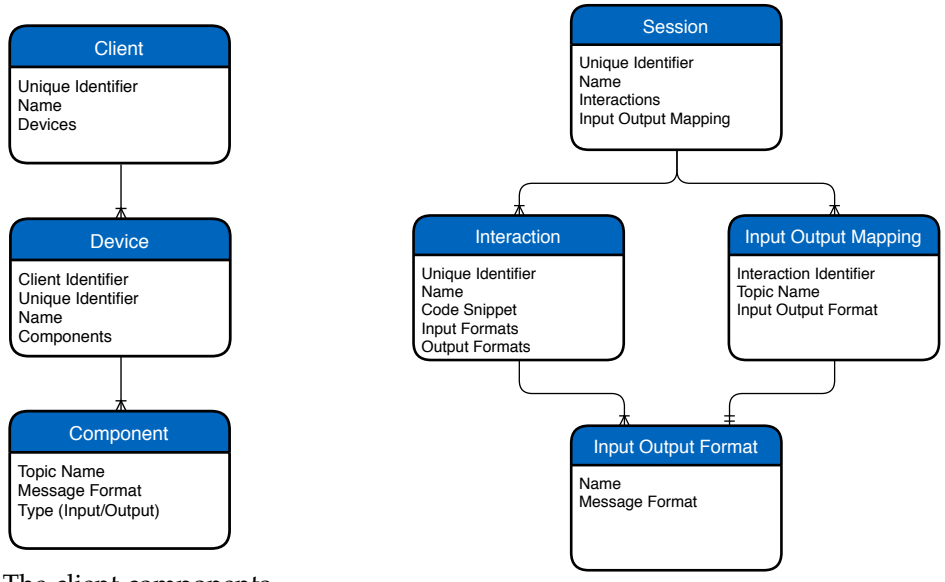
Message Formats are strings which identify a certain data format. Most common data types are available, like for example *Vector4×4*, *Vector2* or *Vector3*.

Topics are data channels which are addressed by a name. Clients can publish messages to topics, which are registered by a device. Clients are also able to receive messages, after subscribing to a topic. Such messages (also called “topic data”)

are formatted as JSON[1]-string, whose structure is defined by the device.

Sessions operate on the server, but can be specified by the client. They are defined by a unique identifier as well as a list of interactions and **input/output mappings**. The mappings are defined by a message format and topic name.

Interactions are reactive components. They operate on topics and are defined by a source code snippet[2]. Interactions are executed in a fixed interval on the UBII server. They can subscribe to topics and use the received topic data as input, given an input/output mapping description. The output of the interaction is published into another topic. It is also possible to keep data to use in future executions (persistent state).



(a) The client components.

(b) The session components.

Figure 2.1: Relationships of the core components in an entity relationship diagram.

2.1.2 Interactions

An powerful but optional core feature of UBII are so called interactions. As explained in the component overview (see 2.1.1), they are reactive components, which operate

[1]JSON is a standardized data exchange format, that uses human-readable text. It is often used for web-based data communication.

[2]Currently only JavaScript is supported as a script language.

on topics and regularly execute given code snippets (processing functions) on the UBII server. Interactions are isolated components, which just depend on topic data and nothing else. This abstraction introduces the possibility to reuse logic in other applications in similar context.

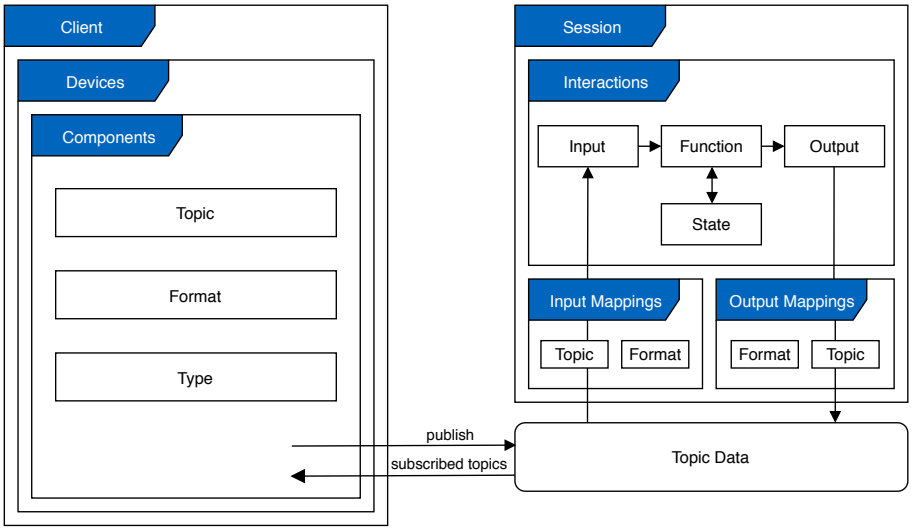


Figure 2.2: Interaction processing overview. This graphic gives a rough overview of the dataflow when using an interaction. Conceptualized with the help of Sandro Weber.

Interactions should be designed generalized, so that they are easy to reuse. They can be used to discretize data, converting data to other formats or just to outsource some logic from the application. Concrete examples include detecting button presses, transforming coordinates and evaluate data.

They are also useful, if you want to connect two topics with different formats. Imagine an application, which consumes a rotation given in euler angles in radians. But some devices publish euler angles in degrees. We could implement an interaction, which takes euler angles in degrees from one topic and publishes euler angles in radians to another one, which then is used by the application.

```
1  // detect intentional movement by comparing the current position with a previous one
2  function (inputs, outputs, state) {
3    const threshold = 0.05;
4
5    if (state.position) {
6      const vector = {
7        x: inputs.position.x - state.lastPosition.x,
8        y: inputs.position.y - state.lastPosition.y,
9      };
10
11     const squaredDistance = Math.pow(vector.x, 2) + Math.pow(vector.y, 2);
12
13     outputs.moved = squaredDistance < threshold;
14   } else {
15     outputs.moved = true;
16   }
17
18   state.lastPosition = inputs.position;
19 }
```

Figure 2.3: An example for an interaction written in JavaScript. This interaction calculates the squared distance of two points. One of the points comes from the input, while the other one is stored in the state. To achieve this, the euclidean vector norm of the subtraction of both vectors without the square root is calculated and compared with a threshold constant. The result is then written into the output as a boolean data type.

The code snippet has to define a function, which accepts three parameters: `inputs` is a collection of values, which contains values which were published into a topic. The topic which was used, is defined by the input mappings of the session. `outputs` is an empty collection, where values can be added. Those values are then published into a topic, defined by the output mappings of the session. `state` stores a persistent collection of values, which can be used in later executions of the same interaction.

2.2 Technology Stack

Since most of the existing software for UBII was written in JavaScript (JS)[1] using a fully web-based architecture, I decided to adapt this approach. This has one major advantage: platform independence. Most modern devices can run web-based software,

[1]JS is a just-in-time compiled scripting language, widely used in web technology. It is a dynamic prototype-based language, which supports object-orientated programming.

which means they can also run the software. Also the software is served by a web server, which means the user does not have to install the software onto his device.

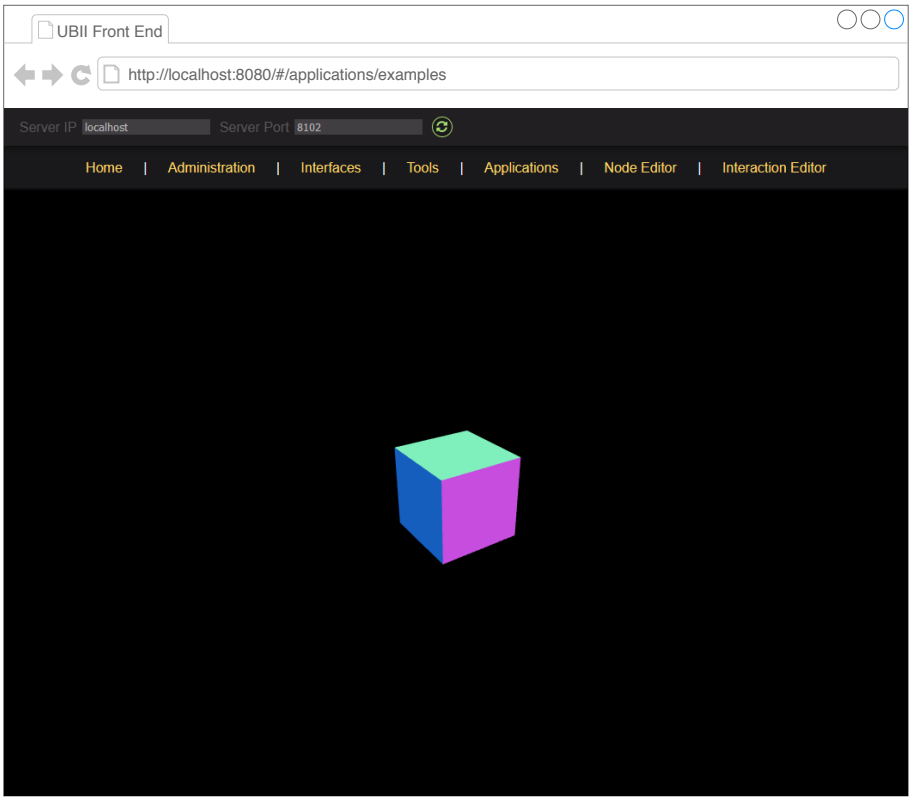


Figure 2.4: A screenshot of the UBII front end rendering a 3D cube.

A web interface with some UBII content (the UBII front end), demos and debugging tools was already written[1], so I included my demos in this interface as well. The technology stack of the front end was built with the following technologies:

Web APIs are Application Programming Interfaces (APIs) available in modern web browsers to provide access to functionality or data outside the browser. The WebAPI is an additional layer of abstraction on top of the operating system ones. While this has the advantage that the API is the same on every device, this also prevents the access to the raw sensor data[2]. In this thesis the WebVR API, which enables to render to external Virtual Reality (VR) headsets and the device orientation API, which gives access to the data of the Inertial Measurement

[1]The front end was developed by Sandro Weber, Daniel Dyrda and me.
[2]The specification is available on www.w3c.github.io/deviceorientation

Unit (IMU)[1] of a device, are used.

Vue.js [2] is a modern open source JavaScript web framework[3] [Eva19]. Being released in 2014 and developed by Evan You, it is a relatively young framework [Koe16, p. 17]. But it quickly gained traction and is quite popular now [Koe16, pp. 12 sq.]. Modules like Vue.js itself, Vue.js plugins and other JavaScript libraries are managed using the package manager npm [4].

Three.js [5] is a lightweight open source library which utilizes WebGL to render Three-dimensional (3D) computer graphics [Ric19]. It can be used to render scenes to the display as well as to a VR headset using WebVR. This high-level library comes with a lot of features, similar to a game engine, like scenes, effects, lights, animation, geometrie and much more.

UBII Client is an JavaScript client for the UBII system. It abstracts the protocol and provides high-level functions to register devices as well as send and receive topic data.

2.3 Smart Device

The "Smart Device" is a part of the UBII front end. Because it is web-based, only data which is available through the **Web APIs** can be obtained. Since it was not designed for a specific use case, it is thought as general purpose or testing device. Only touch positions, touch events, orientation and acceleration is sent to different topics using the **UBII Client**. For more specific scenarios, the smart device can not be used and a custom interface has to be implemented. For the experiments in this thesis though, the smart device client was sufficient, after implementing some improvements.

The data which is published, is also displayed on the screen for debugging purposes. It is possible to set the view in full screen mode, to prevent unintentional interactions with control elements of the web browser or the operating system. Since the reference system for the orientation is fixed to the earth [Dev19, Chapter 4.1], a calibration system was implemented. With the press of the "Calibrate" button, the device is calibrated to

[1] An IMU is an electronic component which is part of most smart phones and allows to measure force, angular rate and magnetic field.

[2] Vue.js: Website: www.vuejs.org, Source code: www.github.com/vuejs/vue

[3] A web framework is a software framework which provides a standard way to build web applications. It comes with tools and libraries to automate and make the development of web applications easier.

[4] "NPM" stands for "Node Package Manager" and is also used in the UBII server itself. Website: www.npmjs.com

[5] Three.js: Website: www.threejs.org, Source code: www.github.com/mrdoob/three.js

the new orientation.

The orientation is provided by the **Web API** through the `DeviceOrientation` event.

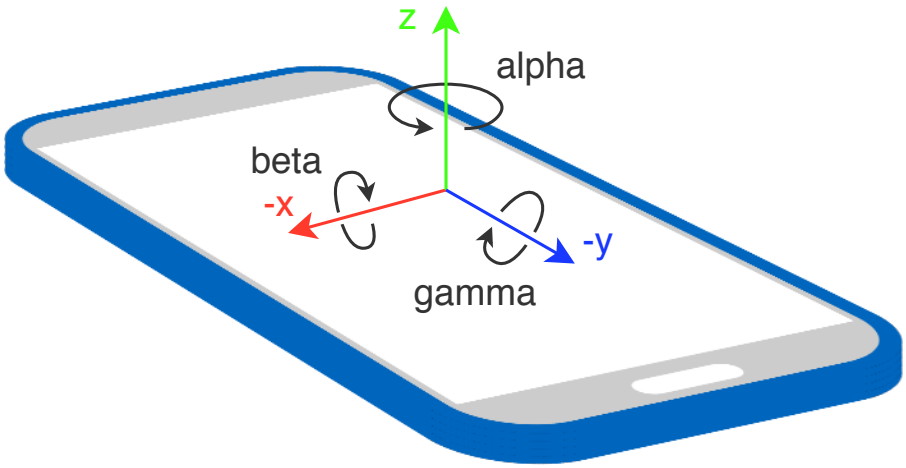


Figure 2.5: The specification of the orientation values visualized. The x and y axes are inverted for the sake of clarity.

3 Introduction

3.1 Section

3.1.1 Cite Tests

Citation test [Afo+17] vs [Afo+17].
More [pre Afo+17, post]
Also possible[2]

Acronym test VR cool.
And a second time VR awesome.

3.1.2 Draw Test

3.1.3 Other Tests

See Table 3.1, Figure 3.2, Figure 3.3, Figure 3.4.

Table 3.1: An example for a simple table.

A	B	C	D
1	2	1	2
2	3	2	3

[2] Afo+17.

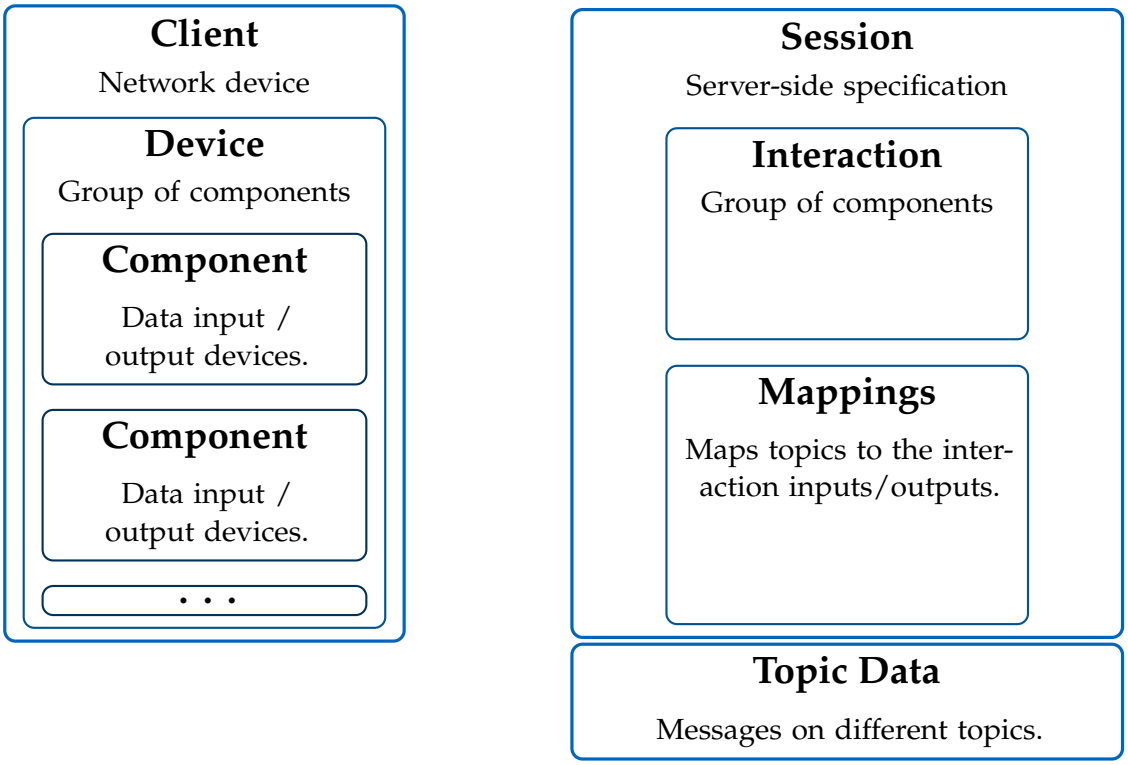


Figure 3.1: Do not forget!

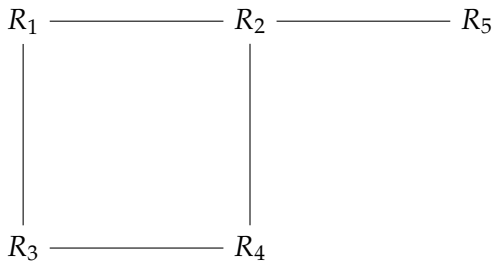


Figure 3.2: An example for a simple drawing.

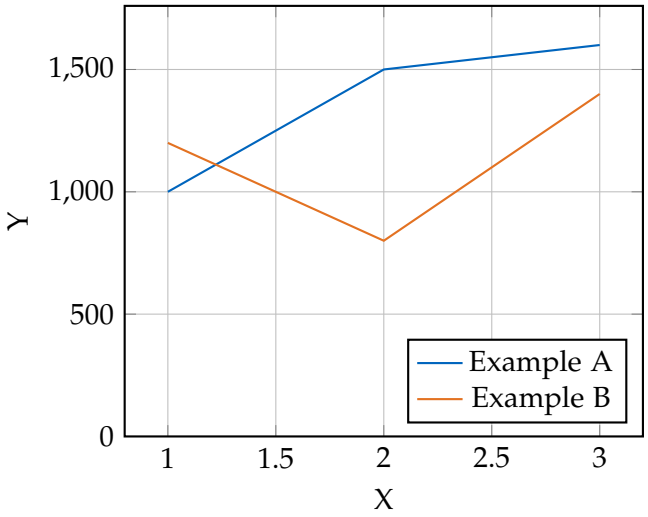


Figure 3.3: An example for a simple plot.

```
1  SELECT * FROM tbl WHERE tbl.str = "str"
```

Figure 3.4: An example for a source code listing.

List of Figures

List of Tables

Bibliography

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