Chair for Computer Science 10 (Media Computing and Human-Computer Interaction)

RWTH AACHEN UNIVERSITY

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Thesis
submitted to the
Media Computing Group
Prof. Dr. Jan Borchers
Computer Science Department
RWTH Aachen University

*by*
*<author_name>*

Thesis advisor:
Prof. Dr. Jan Borchers

Second examiner:
<second_examiner>

Registration date: <registration date>
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# Abstract

A lot of research is going into underwater global positioning systems since radio waves do not propagate underwater. However, the few underwater navigation approaches out there use bulky screen devices which are held in hand. This leads to constrained movement, is rather distractive, and prone to varying brightness conditions. In this master thesis we describe the construction of a prototype, which incorporates several feedback methods, and its evaluation. We implement a vibration motor, a red LED, and a peltier element in diving goggles and a headband. Additionally waterproof in-ear headphones were used for auditory feedback. Since these devices are worn on the head they allow an unintrusive way to give low level directional cues. In a user study we evaluate the feedback methods ashore as a baseline and compare it to their performance underwater and gather additional qualitative feedback of the participants.

# Überblick

Global Positioning Systeme für Navigation unter Wasser ist ein aktuelles Forschungsgebiet, da Radiowellen unter Wasser nicht übertragen werden. Die wenigen Systeme, die Unterwassernavigation zu einem gewissen Level umsetzen, nutzen Bildschirme, die in der Hand gehalten werden. Das ist behindert die Bewegungsfreiheit, ist eher ablenkend und die Sichtbarkeit ist beeinflusst durch sich ändernde Lichtverhältnisse. In dieser Masterarbeit wird die Konstruktion eines Prototypen beschrieben, der verschiedene Feedbackmethoden beinhaltet und deren Auswertung. Wir benutzen einen Vibrationsmotor, eine rote LED und ein Peltierelement in einer Taucherbrille und Stirnband. Zusätzlich verwenden wir wasserfeste In-Ohr-Kopfhörer für Akustisches Feedback. Da diese Geräte direkt am Kopf getragen werden, ermöglichen sie einen unaufdringlichen Wege Richtungsangaben auf niedrigem Level zu vermitteln. In einen Benutzerstudie werten wir die verschiedenen Feedbackmethoden an Land aus und vergleichen die Leistung mit der unter Wasser. Zusätzlichen sammeln wir qualitatives Feedback der Teilnehmer.

# Acknowledgements

Thank you!

# Conventions

Throughout this thesis we use the following conventions.

*Text conventions*

Definitions of technical terms or short excursus are set off in coloured boxes.

**EXCURSUS:**
Excursus are detailed discussions of a particular point in a book, usually in an appendix, or digressions in a written text.

Definition: *Excursus*

Source code and implementation symbols are written in typewriter-style text.

`myClass`

The whole thesis is written in Canadian English.

Download links are set off in coloured boxes.

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# Chapter 1

# Introduction

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# Chapter 2

# Related work

In this chapter we give an overview of related work and research in the the fields of under water navigation systems. It is divided into three parts. First we give an overview of currently used technology used for underwater position tracking and the issues in comparison with common GPS. Second it covers existing systems which incorporate position tracking and underwater feedback today and third research regarding several feedback modalities.

ToDo: fix citation

## 2.1 Technology for Underwater Positioning Systems

It is commonly known that radio signals do not propagate underwater. Currently state of the art solutions consists of large and expensive inertial measurement units. Those are for example used in submarines and use the last known position in combination with military grade accelerometer and diving depth to interpolate the current location [**?**].

undewater data fusion

**?** developed a data fusion approach for underwater position tracking using the data from a bow array and a side array of sonar sensors. Their method address issues of data fusion like time-space normalization and data transfer rates. It has been evaluated by running numerical simulations.

## 2.2 Underwater Navigation Systems

Navimate

? developed Navimate which uses a floating radio antenna for GPS and several underwater transducers to communicate with a wrist-worn device via acoustic signals. The device receives the signals and uses the information of the GPS and the transducers to determine its location and presents the information on the screen.

NavDive

? built NavDive which uses a floating GPS receiver wired to a mobile receiver held by the diver. It shows the direction to previously set locations and positional information in text form. A desktop application lets the user inspect their diving path and add landmarks for locations of interest.

Ariadna Tech

? developed a system which uses an initial GPS location from the wrist unit before submerging and switches to inertial sensors afterwards. The sensors track the divers real-time position, speed, heading, and distance information using a navigation transmitter worn on the leg. It calculates the information in real-time and sends it wireless to to the wrist unit which displays it on screen.

? uses four receiver and

## 2.3 Feedback modalities

# Chapter 3

# Hardware Prototype and Software

In this chapter we present the construction of the hardware setup and the user study software. Furthermore we talk about the technical considerations regarding each component and their feasibility.

## 3.1 System Design

The aim of this thesis is to investigate the perception of several feedback modalities underwater and their feasibility for low level navigation cues. We include visual, auditory, and tactile feedback in form of a LED, waterproof in ear headphones, a vibration motor, and a thermoelectric cooling module. The prototype has to incorporate these methods as unobtrusive and comfortable as possible in particular when they are inactive. Electronic connections have to be waterproof, undisturbing, and failsafe. Furthermore all components should be affordable to provide an advantage over commercial solutions.

To investigate the recognition times and comfort of each technique we built a prototype composed of one LED in the diving goggles as well as a waterproof vibration motor and a peltier cooling module in a stretchable headband. The headphones are provided separately.

**Visual Feedback** To provide visual low level feedback we use a common red 5mm LED. An issue regarding luminous light emitted by an LED is its proneness to water reflections. These reflections change rapidly due to water undulation and exterior lighting. The color of the surroundings influence it as well. For example light blue tiles in a swimming pool render a blue LED almost undetectable. To provide clear recognizable feedback we tested several colors underwater and came to the conclusion that red LED is better recognizable than other common LED colors.

**Auditory Feedback**

**Vibration Feedback**

**Thermal Feedback**

### 3.1.1 Hardware Setup

### 3.1.2 Testing

### 3.1.3 Safety

## 3.2 Software

# Chapter 4

# Evaluation

In this chapter we will evaluate our prototypes with respect to the quantitative and qualitative aspects of the different feedback methods. We are interested to what extent the perception of feedback differs onshore versus underwater regarding time until the stimulus is perceived. Afterwards the user gives feedback in order to tell if the conditions make a difference with respect to preference.

Since vibro-tactile and visual feedback is common today for several application ashore we let users test it onshore as well as under water. We drop sound in the underwater condition since it requires specific waterproof earphones or bone conduction headphones. Both exist and provide a comparable quality. The wireless connection however is not trivial underwater. Auditory feedback is broadly used in today's traffic and therefore not of particular interest in our case.

## 4.1 User Study

The user study is divided into two groups. The first one is testing the prototype under normal condition while sitting on a chair where the other group is examining the feedback underwater.

# Chapter 5

# Summary and future work

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## 5.1 Summary and contributions

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## 5.2 Future work

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# Appendix A

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# Appendix B

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