Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Autonomous Systems Lab
Prof. Roland Siegwart

Bachelor-Thesis

Human-Machine Interface for Operating a Blimb

Spring Term 2012

Supervised by:
Konrad Rudin
Mora Javier Alonso
Paul Beardsley XXXXX

Authors:
Krebs Matthias
Ledergerber Anton

Declaration of Originality

I hereby declare that the written work I have submitted entitled

Human-Machine Interface for Operating a Blimb

is original work which I alone have authored and which is written in my own words.[1]

Author(s)

Anton	Ledergerber
Matthias	Krebs

Supervising lecturer

Konrad	Rudin
Javier Alonso	Mora
Paul XXX	Beardsley XXX

With the signature I declare that I have been informed regarding normal academic citation rules and that I have read and understood the information on 'Citation etiquette' (`http://www.ethz.ch/students/exams/plagiarism_s_en.pdf`). The citation conventions usual to the discipline in question here have been respected.

The above written work may be tested electronically for plagiarism.

Place and date	Signature

[1]Co-authored work: The signatures of all authors are required. Each signature attests to the originality of the entire piece of written work in its final form.

Inhaltsverzeichnis

Abstract

Hier kommt der Abstact hin . . .

Acknowledgements

Without the help of a few people this thesis would not have been possible. We received the necessary support from all sides throughout the project to realize the this HMI which we are proud of.
Prof. Dr. Roland Y. Siegwart
Dr. Paul Beardsley
PhD students Konrad Rudin and Javier Alonso Mora
Gerhard Röthlin
Lorenz Meier
Alexander Rudyk

Symbols

Symbols

ϕ, θ, ψ	roll, pitch and yaw angle
b	gyroscope bias
Ω_m	3-axis gyroscope measurement

Indices

x	x axis
y	y axis

Acronyms and Abbreviations

ETH	Eidgenössische Technische Hochschule
EKF	Extended Kalman Filter
IMU	Inertial Measurement Unit
UAV	Unmanned Aerial Vehicle
UKF	Unscented Kalman Filter

Kapitel 1

Introduction

1.1 Context

1.2 Goals

1.3 System Overview

1.4 Similar Systems and their HMI

1.5 Structure of the Report

Kapitel 2

Einige wichtige Hinweise zum Arbeiten mit LaTeX

Nachfolgend wird die Codierung einiger oft verwendeten Elemente kurz beschrieben. Das Einbinden von Bildern ist in LaTeX nicht ganz unproblematisch und hängt auch stark vom verwendeten Compiler ab. Typisches Format für Bilder in LaTeX ist EPS[1].

2.1 Gliederungen

Ein Text kann mit den Befehlen `\chapter{.}`, `\section{.}`, `\subsection{.}` und `\subsubsection{.}` gegliedert werden.

2.2 Referenzen und Verweise

Literaturreferenzen werden mit dem Befehl `\cite{.}` erzeugt. Ein Beispiel: [3].
Zur Erzeugung von Fussnoten wird der Befehl `\footnote{.}` verwendet. Auch hier ein Beispiel[2].
Querverweise im Text werden mit `\label{.}` verankert und mit `\ref{.}` erzeugt. Beispiel einer Referenz auf das zweite Kapitel: Kapitel 2.

2.3 Aufzählungen

Folgendes Beispiel einer Aufzählung ohne Numerierung,

- Punkt 1
- Punkt 2

wurde erzeugt mit:

```
\begin{itemize}
  \item Punkt 1
  \item Punkt 2
\end{itemize}
```

Folgendes Beispiel einer Aufzählung mit Numerierung,

1. Punkt 1

[1]Encapsulated Postscript
[2]Bla bla.

2. Punkt 2

wurde erzeugt mit:

```
\begin{enumerate}
  \item Punkt 1
  \item Punkt 2
\end{enumerate}
```

Folgendes Beispiel einer Auflistung,

P1 Punkt 1

P2 Punkt 2

wurde erzeugt mit:

```
\begin{description}
  \item[P1] Punkt 1
  \item[P2] Punkt 2
\end{description}
```

2.4 Erstellen einer Tabelle

Ein Beispiel einer Tabelle:

Tabelle 2.1: Daten der Fahrzyklen ECE, EUDC, NEFZ.

Kennzahl	Einheit	ECE	EUDC	NEFZ
Dauer	s	780	400	1180
Distanz	km	4.052	6.955	11.007
Durchschnittsgeschwindigkeit	km/h	18.7	62.6	33.6
Leerlaufanteil	%	36	10	27

Die Tabelle wurde erzeugt mit:

```
\begin{table}[h]
\begin{center}
 \caption{Daten der Fahrzyklen ECE, EUDC, NEFZ.}\vspace{1ex}
 \label{tab:tabnefz}
 \begin{tabular}{ll|ccc}
 \hline
 Kennzahl & Einheit & ECE & EUDC & NEFZ \\ \hline \hline
 Dauer & s & 780 & 400 & 1180 \\
 Distanz & km & 4.052 & 6.955 & 11.007 \\
 Durchschnittsgeschwindigkeit & km/h & 18.7 &  62.6 & 33.6 \\
 Leerlaufanteil & \% & 36 & 10 & 27 \\
 \hline
 \end{tabular}
\end{center}
\end{table}
```

2.5 Einbinden einer EPS-Graphik

Das Einbinden von Graphiken kann wie folgt bewerkstelligt werden:

```
\begin{figure}[h]
   \centering
   \includegraphics[width=0.75\textwidth]{pics/k_surf.eps}
   \caption{Ein Bild.}
   \label{pics:k_surf}
\end{figure}
```

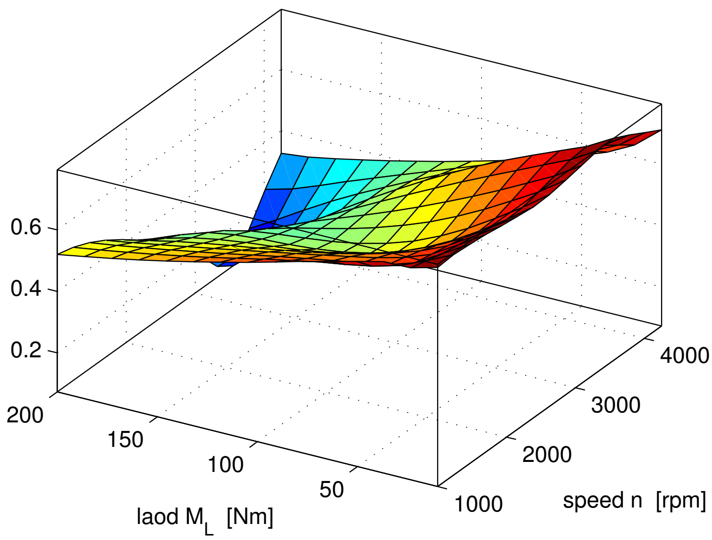

Abbildung 2.1: Ein Bild.

oder bei zwei Bildern nebeneinander mit:

```
\begin{figure}[h]
  \begin{minipage}[t]{0.48\textwidth}
    \includegraphics[width = \textwidth]{pics/cycle_we.eps}
  \end{minipage}
  \hfill
  \begin{minipage}[t]{0.48\textwidth}
    \includegraphics[width = \textwidth]{pics/cycle_ml.eps}
  \end{minipage}
  \caption{Zwei Bilder nebeneinander.}
  \label{pics:cycle}
\end{figure}
```

Bemerkung: Ersetzt man den Positionierungsparameter `h` durch `H`, so wird das Gleiten der Abbildung verhindert.

2.6 Mathematische Formeln

Einfache mathematische Formeln werden mit der equation-Umgebung erzeugt:

$$p_{me0f}(T_e, \omega_e) \; = \; k_1(T_e) \cdot (k_2 + k_3 S^2 \omega_e^2) \cdot \Pi_{max} \cdot \sqrt{\frac{k_4}{B}} \, . \qquad (2.1)$$

Der Code dazu lautet:

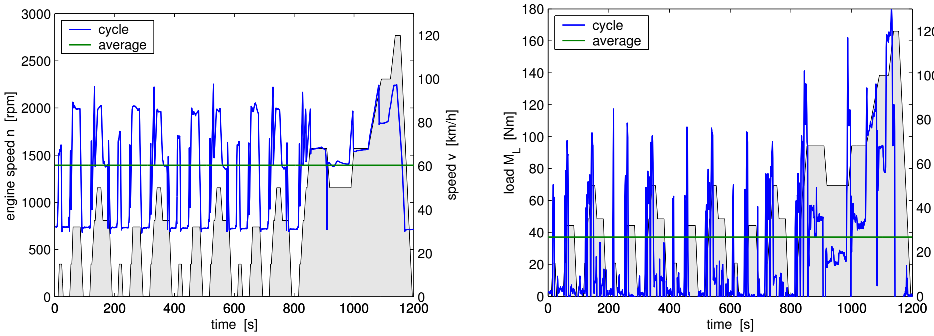

Abbildung 2.2: Zwei Bilder nebeneinander.

```
\begin{equation}
 p_{me0f}(T_e,\omega_e) \ = \ k_1(T_e) \cdot (k_2+k_3 S^2
 \omega_e^2) \cdot \Pi_{max} \cdot \sqrt{\frac{k_4}{B}} \, .
\end{equation}
```

Mathematische Ausdrücke im Text werden mit \$formel\$ erzeugt (zB: $a^2 + b^2 = c^2$).

2.7 Weitere nützliche Befehle

Hervorhebungen im Text sehen so aus: *hervorgehoben*. Erzeugt werden sie mit dem `\epmh{.}` Befehl.

Kapitel 3

Finding a Hardware and Software Solution

References to [?]

Kapitel 4

The different Control Modes

Kapitel 5

Realization of the HMI as a whole and for each Control Mode

Kapitel 6

Trajectory Planning

For the two most advanced modes, i. e. the Half-Automatic and the Full-Automatic Mode, trajectories had to be generated. In this chapter the best trajectories for skye are elaborated.

6.1 Introduction

6.1.1 Definition

What is a trajectory...(notation, parameter, time...) How do we intend to realize our idea...

6.1.2 Our Approach

From the GUI it was given that the goal trajectory would be a multipoint-interpolating trajectory. The user is able to define waypoints on a map which afterwards should be connected with a reasonable and realizable trajectory. Beside interpolating trajectories there exist also approximating trajectories but they were not taken into consideration, since usually the user wants skye fly directly through a waypoint.
In another Bsc Thesis elaborated in this project a controller for waypoint following was designed. So it was convenient in the scope of this Thesis to use this controller instead of a specialized trajectory controller.

6.2 Vorschlag: Geometric Parameterized Paths

BLA: Everything considering generating splines, boundery conditions, order, and comparision and evaluation (skye independent)

6.3 Vorschlag: Time Parameterized Trajectories

BLA: System constraints, time parametrization

6.4 Vorschlag: Trajectory Tracking

BLA: Feeding the trajectories into skye, controller appoach, evaluation (comparision trajectory and trace)
UNSCHÖN: Hier muss alles was oben theoretisch beschrieben wird repetiert werden

(BC, Order, Constraints?, different time parametrization)
The goal of tracking is

6.5 System Constraints for Trajectory

6.5.1 Maximum Velocities and Accelerations

In order to plan a feasible trajectory one has to know the capabilities of the system. Here just a basic derivation for the velocities and accelerations is given, for more details refer to (!!!!Bsc Thesis Joe, Bsc Thesis Andy)

The maximum feasible acceleration in any direction is calculated to be:

$$|a_{max}| = \frac{|F_{res,w}|}{m_{tot}} = 0.96 m/s^2 \tag{6.1}$$

Whereas the $F_{res,w}$ is the force resulting from all four thrusters operated under full load in the worst direction and m_{tot} is the sum of the masses of the helium, the virtual mass and the mass of the system itself.

The maximum feasible velocity in any direction is calculated to be:

$$|v_{max}| = \sqrt{\frac{|F_{res,w}|}{\frac{1}{2} c_d \rho \pi r^2}} = 4.7 m/s \tag{6.2}$$

which is nothing but $|F_{res,min}| = |F_{dray}|$.

For trajectories for position and orientation the maximal feasible angular acceleration is also important. It is calculated to be:

$$|\Psi_{max}| = \frac{|M_{res,w}|}{|\lambda_{max,J_B}|} = 2.82 rad/s^2 \tag{6.3}$$

which is quite conservative because it is assumed that worst axis for turning is also the principle axis of the inertia tensor with the highest inertia.

Since the system is almost undamped for rotations, the rotational velocities will never be the limiting factor.

6.5.2 Continuity

6.6 Definition

6.6.1 Paths and Trajectories

6.6.2 Interpolation and Approximation

6.6.3 Parametrization

6.6.4 Experimental Design

6.7 Spline Theory

references to [1], [2] and [**?**]

6.7.1 Piecewise Polynomial Interpolating Splines

Boundary Conditions

Polynomial Order

Parametrization

6.7.2 B-Splines

Boundary Conditions

Polynomial Order

Parametrization

6.8 Trajectory Generation

6.8.1 System Constraints

6.8.2 Time Parametrization

6.9 Controller Implementation

6.9.1 Trajectory Controller

see [3] and [4]

6.9.2 Pure Pursuit Position Controller

see also [3]

6.9.3 Cross Track Error Controller

see [5]

6.10 Discussion

Literaturverzeichnis

[1] G. Engeln-Müllges, K. Niederdrenk, R. Wodicka: *Numerik-Algorithmen : Verfahren, Beispiele, Anwendungen.* Springer Verlag, 2011.

[2] L. Biagiotti, C. Melchiorri: *Trajectory Planning for Automatic Machines and Robots.* Springer Verlag, 2008.

[3] J. M. Snider: *Automatic Steering Methods for Autonomous Automobile Path Tracking.* Research Report CMU-RI-TR-09-08, Robotics Institute Carnegie Mellon University Pittsburgh, Pennsylvania, 2009.

[4] A. De Luca, G. Oriolo, C. Samson: *Feedback Control of a Nonholonomic Car-Like Robot.* In Robot Motion Planning and Control, pages 171-249, 1998.

[5] D. L. Williams: *Loitering Behaviors of Autonomous Underwater Vehicles.* MSc thesis, Naval Postgraduate School, Monterey, California, 2002.

[6] T. Kammermann: *Evaluation and implementation of a control device for a ballbot.* BSc thesis, ETH Zurich, 2010.

[7] S. Dössegger: *Time-optimal trajectories for a Ballbot.* BSc thesis, ETH Zurich, 2010.

[8] J. Weichart: *Agile Blimp Modeling and Simulation Environment.* BSc thesis, ETH Zurich, 2012.

[9] D. Meier, L. Müri: *Agile Blimp Controller Design.* BSc thesis, ETH Zurich, 2012.