Impact of Varying Collision Avoidance Strategies on Human Stress Level in Human-Robot Interaction

Master Thesis

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by

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“*Das ist die Widmung / This is the dedication (optional)*”

Acknowledgement

Das ist die Danksagung / This is the acknowledgement (optional)

Abstract

Das ist die Kurzfassung (siehe Abschnitt 1.3) / This is the abstact (see section 1.3).

Contents

1 Introduction

1.1 Motivation

Industry 4.0, or the Fourth Industrial Revolution, has significantly transformed the industry, especially in the manufacturing sector by introducing "smart" technologies such as the Internet of Things (IoT), cloud connectivity, big data, Human-robot collaboration etc. This revolution has seen drastic improvements and innovation with enhanced efficiency and productivity being the core principle a nd driving force of innovation in Industry 4.0. Human-robot collaboration, a key component of Industry 4.0, has played a huge role in this advancement by bringing humans closer together and facilitating more efficient and cooperative workflows.

Looking ahead to the future of the emerging Industry 5.0, the focus shifts towards a more human-centric approach. Industry 5.0 aims to balance technological advancements with human needs and interests, emphasizing sustainable and resilient industrial practices. It seeks to merge the technological efficiency of Industry 4.0 with a greater emphasis on enhancing human well-being and personalizing the production process. Industry 5.0 brings back the human workforce to the factory, where humans and machines are paired to increase process efficiency by utilizing human brainpower and creativity through the integration of workflows with intelligent systems Nahavandi (2019)[1]. This shows a significant shift from purely efficiency-driven operations to those that also prioritize human factors and environmental sustainability.

Traditionally, robots have been separated from human workers due to safety concerns and other factors. However, advancements in Industry 4.0 have significantly increased human-robot collaboration, bringing them closer together to jointly accomplish tasks. This evolution has seen robots move from being isolated behind safety barriers to now working side-by-side with human counterparts, effectively leveraging their unique strengths combining human flexibility and decision-making skills with the precision and consistency of robots.

While technological advancements aim to optimize production, the comfort and well-being of human workers have not always been prioritized. This thesis aims to delve into the human aspect of human-robot interaction, considering how proximity to robots might affect the operator's physiological state. It aims to explore how continuous interaction with robots affects human stress levels. Monitoring and accurately assessing stress levels in human-robot collaborative environments is crucial. Elevated stress can lead to fear and doubt, negatively impacting productivity and the effectiveness of human-robot collaboration. This can also hinder the full utilization of the advanced capabilities of collaborative robots. Identifying and addressing these stress factors is key to optimizing the human-robot collaboration for enhanced productivity and a harmonious working environment.

1.2 Aim of the Thesis

The title page provides information about the topic of the thesis, the chair, date of submission and the name of the author in the corresponding entries of the template.

1.3 Literature Review

T

- introduction
- theoretical foundations
- your approach and investigations
- experimental/simulation results and analysis
- summary and outlook

2

Theoretical foundation

2.1 Stress Framework/Biosignals

2.1.1 Photoplethysmogram-PPG

2.1.2 Electrodermal Activity-EDA

2.1.3 Motion Capture

LaTeXpackages and compilers have the advantage that they can be installed completely independently of the latex editor. They are summarized in so-called latex distributions. Recommended distributions on Windows are MikTeX (http://miktex.org/) and on OS X MacTeX https://tug.org/mactex/.
The choice of latex editor is usually based on individual needs and tastes. A recommended, cross-platform editor is TeXstudio http://texstudio.sourceforge.net/. This offers, among other things, the possibility to display desired positions of the PDF preview directly in the source text. Another popular editor is TeXnicCenter (http://www.texniccenter.org/). Finally, the author chooses between the Latex- (PS/Dvi) and the pdflatex compiler. The respective selection are made in the settings of the editor.

Pdflatex:

- More advanced than latex
- Supports the following image file types: PDF (Vector), PNG, JPG.
- Supports EPS images with the package "‘epstopdf"’ (already included).
- Not compatible with old packages that only work with PostScript files.

Latex (PS/Dvi):

- Works with "‘psfrag"’ and other PS based packages.
- Supports EPS images only without further conversion.
- Longer compile time

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2.2 Robot Collision Avoidance

2.3 Machine Learning Methods

Insert a table next to a figure taking into account the associated directories (tables, figures):

Configuration	Parameter set
1	$\{p_1, p_2, p_5\}$
2	$\{p_1, p_4, p_5\}$
3	$\{p_2, p_3, p_4\}$

Table 2.1: Definition range of parameters for optimization.

Figure 2.1: Sample diagram

The *Subcaption* package (labeling of tables and figures with a), b), ...) should only be chosen if the associated tables/figures really belong together contextually.

(a) TU Dortmund Logo

(b) RST Logo

Figure 2.2: Collection of all logos

For long descriptive texts, the *Subfigure-Caption* can be left blank. A description with reference to the letters a), ..., then takes place in the general description.
Table 2.2 lists all parameters used. Table 2.2a ...

Table 2.2: Main numbering

(a) Table on the left

Configuration	Parameter set
1	$\{p_1, p_2, p_5\}$
2	$\{p_1, p_4, p_5\}$
3	$\{p_2, p_3, p_4\}$

(b) Table on the right

Configuration	Parameter set
1	$\{p_1, p_2, p_5\}$
2	$\{p_1, p_4, p_5\}$
3	$\{p_2, p_3, p_4\}$

Tikz is an extensive LaTeXpackage to create images using program instructions. Several LaTeX examples are available at the following link:
http://www.texample.net/tikz/examples/
A particularly useful tool to create figures is the integration with the Matlab plugin "‘matlab2tikz"’:
http://www.mathworks.com/matlabcentral/fileexchange/22022-matlab2tikz
converts images created in Matlab to a tikz image. One advantage is the easy way to adjust afterwards any attributes of the image or the drawing: line color, width, type, grid, legends, markers, u.a.
The basic procedure starts with creating the Tikz code:

1. Create Matlab drawing and bring it to the foreground (it is better to close all other pictures). Attributes of the drawing can also be adjusted here (grid, line color, width, log scaling, ...).

2. After adding "‘matlab2tikz"’ in the Matlab paths, the image can be converted: *matlab2tikz(’myfile.tikz’);*

3. The file *myfile.tikz* now contains the Tikz-Code.

In principle, Tikz-Code can be processed directly in the Latex document within the *tikzpicture* environment. However, this variant scales poorly with the capacities of the latex compiler. Especially with multiple graphs from Matlab, which can sometimes contain many data points, the compiler might crash with memory errors. It is therefore advisable to compile each Tikz image as a separate Latex instance and then include it as a PDF. To simplify this, we make use of the *standalone* package. Including the Tikz code in the *standalone* environment is done as follows:

1. The *standalone* environment is built like a standalone latex document. It starts with a *documentclass* and wraps the *tikzpicture* environment inside a *document* environment. The preamble loads appropriate packages (e.g. tikz, pgfplots, fonts, math, ...) and defines needed styles.

2. If the *standalone* class is chosen as the class, the resulting PDF of the standalone latex document is already cropped to the dimensions of the content/image. Furthermore, the class should have the same font size as the later main document.

3. The standalone latex document can either be compiled by itself, or via *\include-standalone[...]{...}* command in another (main) document. The image should already have the correct dimensions for the target document when it is created so that the *scale=1.0* option can be set. With the option *mode=buildnew* the outsourced image will only be compiled if it has changed. This speeds up the compilation process of the main document considerably in case of many images.

4. The PDFs of the outsourced images that are created in individual instances are located in the same folder as the Tikz code and can also be used for other purposes (presentation, ...).

See the source code of the figure 2.3 as an example of a standalone image environment.

This template is built in such a way that both, the packages from the *shared_packages.tex* file, and the commands from the *commands.tex* file can be included into the *standalone* environment via *\input*. In *shared_packages.tex* the files *colordef.tex* and *tikzdef.tex* are also directly included for custom colors and tikz styles. This way, packages, commands, colors, and styles do not have to be copied into each *standalone* environment, but can be customized in a centralized way.

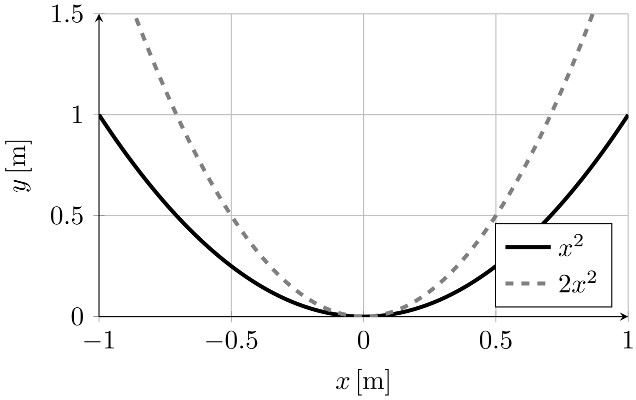

Figure 2.3: Square function

If `matlab2tikz` is used, the Tikz environment first uses the scientific representation of numbers, i.e. depending on the decimal magnitude. The default can be overwritten with the following commands, or a selection of them, can be inserted into the *axis* environment:

- `scaled y ticks = false,`
- `scaled x ticks = false,`
- `y tick label style=/pgf/number format/.cd, fixed, int detect, fixed zerofill, precision=3,`
- `x tick label style=/pgf/number format/.cd, fixed, int detect, fixed zerofill, precision=3`

The first two commands allow you to group the powers of ten so that a common power of ten is appears on both axes. The lower two commands defines the desired precision.

Tikz can generate block diagrams (see above linked examples). A myriad of examples come up in a Google search.

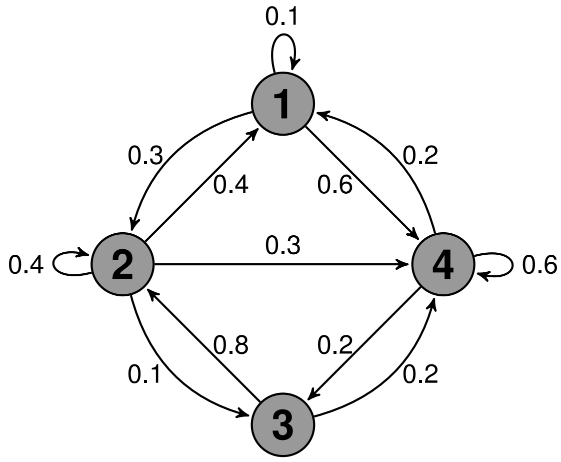

Figure 2.4: Gezeichnet mit Tikz

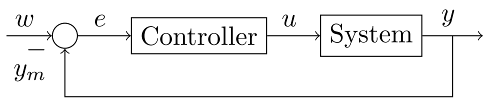

Figure 2.5: Block diagram with Tikz

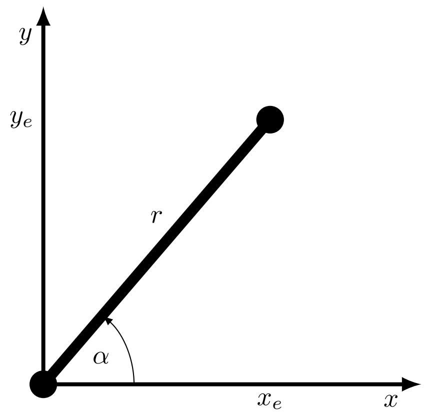

Figure 2.6: Simple drawing with tikz

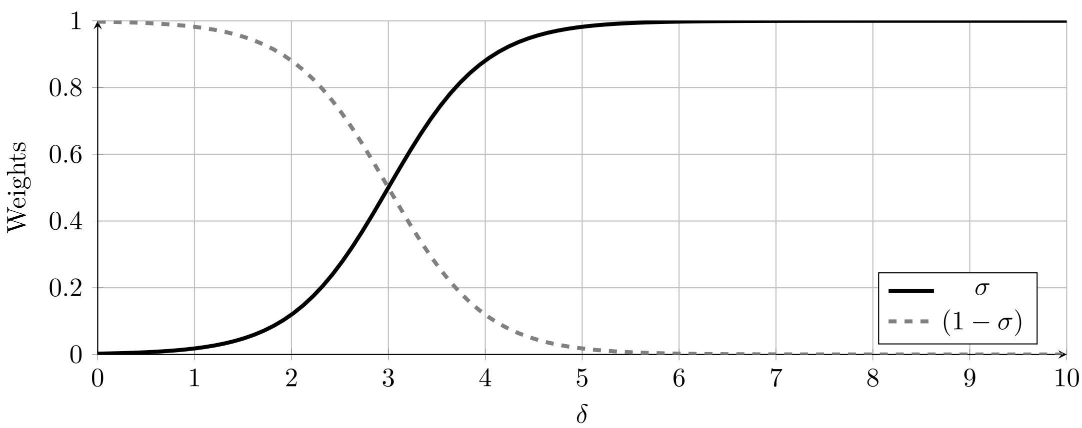

Figure 2.7: Plot with Tikz (without detour via Matlab)

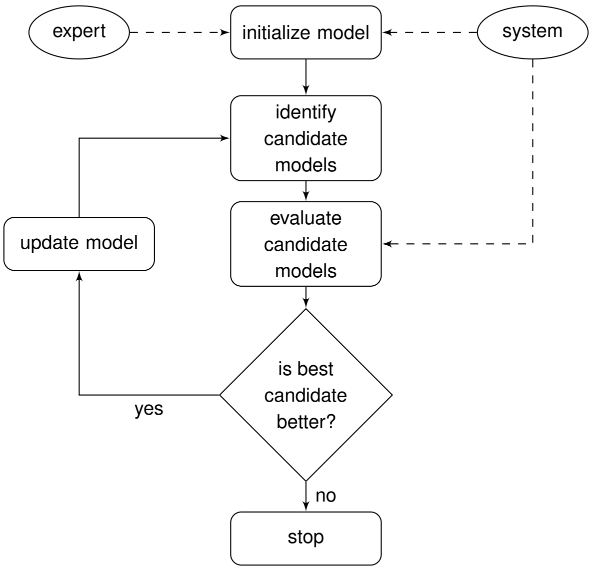

Figure 2.8: Flowchart with Tikz

3
Experiment

3.1 Design of Experiments

3.2 Procedure/Protocol

4 Methodology

4.1 Data Acquisition

4.2 Pre-Processing

4.3 Feature Extraction

4.4 Classification /Stress Detection/

Latex

- *http://miktex.org/*
  Windows Latex Distribution
- *https://tug.org/mactex/*
  Os X Latex Distribution
- *http://texstudio.sourceforge.net/*
  TeXstudio Development environment (recommended)
- *http://www.texniccenter.org/*
  TeXnicCenter Development environment
- *http://de.wikipedia.org/wiki/Hilfe:TeX*
  Collection of mathematical commands
- *http://www.ctan.org/*
  Documentation of all packages
- *http://en.wikibooks.org/wiki/LaTeX/*
  HILFE
- *http://www.texify.com/*
  Try Latex Code by Copy/Paste (Formulas)

Graphics

- *http://www.inkscape.org/*
  Vector graphics

- *http://www.imagemagick.org/*
  converted from *.* to eps

Matlab

- *http://www.mathworks.com/matlabcentral/fileexchange/22022-matlab2tikz*
  exported figure to tikz
- *http://www.mathworks.com/matlabcentral/fileexchange/21286-matlabfrag*
  exported figure to eps + tags
- *http://www.mathworks.com/matlabcentral/fileexchange/23604-fixlines*
  replaces " Matlab " lines with " reasonable " lines
- *http://www.mathworks.com/matlabcentral/fileexchange/23629-exportfig*
  exported figure to eps, pdf, etc. (with fixlines, without tagging)

5
Result

6
Discussion and Conclusion

Bibliography

Nahavandi, S. (2019): "Industry 5.0—A Human-Centric Solution". In: *Sustainability* 11.16. URL: `https://www.mdpi.com/2071-1050/11/16/4371`.

7 Appendix

Das ist der Anhang (siehe Abschnitt ??) / This is the appendix (see section ??)