

Bachelor's thesis



Czech  
Technical  
University  
in Prague

**F3**

Faculty of Electrical Engineering  
Department of Cybernetics

# Extraction of Features from Moving Garment

**Michal Neoral**

CYBERNETICS AND ROBOTICS, Robotics

Květen 2014

Supervisor: Ing. Pavel Krsek, Ph.D.

Draft: 4. 5. 2014



## Acknowledgement / Declaration

Foremost, I would like to thank to  
Ing. Pavel Krsek, Ph.D. ...

**do 11.5.**

Prohlašuji, že jsem předloženou  
práci vypracoval samostatně a že jsem  
 uvedl veškeré použité informační zdroje  
v souladu s Metodickým pokynem o do-  
držování etických principů při přípravě  
vysokoškolských závěrečných prací.

V Praze dne 5. 5. 2013

.....

## Abstrakt / Abstract

Tento...

**do 11.5.**

**Klíčová slova:** dynamický model; model oděvu, textilie; extrakce příznaků; 3D obraz; silueta.

**Překlad titulu:** Získání příznaků z obrazu pohybující se látky

This...

**do 11.5.**

**Keywords:** dynamic model; garment model; feature extraction; 3D image; silhouette.

# Contents /

<b>1 Introduction</b> .....	1
1.1 Motivations .....	1
1.2 Goals .....	1
1.3 The State of the Art .....	1
<b>2 Description of Workplace and of the Software</b> .....	3
2.1 Workplace .....	3
2.1.1 Manipulator .....	3
2.1.2 End Effector .....	5
2.1.3 Sensors .....	5
2.2 Software .....	6
2.2.1 Robot Operating System ..	6
<b>3 Way of getting data</b> .....	7
3.1 Goals of experiment .....	7
3.2 Realisation .....	7
3.3 Capturing of RGB .....	8
3.3.1 External Axis .....	8
3.3.2 Arm with Xtion Sensor ....	8
3.3.3 Arm with Garment .....	8
3.4 Capturing of Depth maps .....	9
3.4.1 External axis .....	9
3.4.2 Arm with Xtion sensor ....	9
3.4.3 Arm with Garment .....	10
3.5 Capturing Background Image .	10
3.5.1 External axis .....	10
3.5.2 Arm with Xtion sensor ..	10
3.5.3 Arm with Garment .....	10
<b>4 Data Structure</b> .....	11
4.1 Format of Recorded Data .....	11
4.2 Topics .....	11
4.3 Measured Data Set of the Garments .....	11
4.3.1 Structure of Data Set ....	11
4.3.2 Format of Names of Recorded Files .....	11
4.3.3 Description of the Garments .....	11
<b>5 Data Processing</b> .....	13
5.1 Load Data to the MATLAB... ..	13
5.2 Extraction of Features from RGB .....	13
5.2.1 Rectification of RGB ....	13
5.2.2 Filtering Background by Use Reference Image .	13
5.2.3 Finding End of Gripper .	13
5.2.4 Finding Central Curve of Garment .....	13
5.2.5 Finding Mathematical Features from RGB .....	14
5.3 Extraction of Features from Depth Map .....	15
5.3.1 Rectification of Depth Map to 3D points .....	15
5.3.2 Filtering by Depth of Area .....	15
5.3.3 Finding Points .....	15
5.3.4 Finding Mathematical Features from Depth Map .....	16
<b>6 Results</b> .....	17
<b>7 Discussion</b> .....	18
<b>8 Conclusion</b> .....	19
<b>References</b> .....	20
<b>A Specification</b> .....	23
<b>B Content of included DVD</b> .....	24
<b>C Abbreviations</b> .....	25
<b>D Brief Manual to Get Data Manually</b> .....	26

## Tables / Figures

<b>4.1.</b> Explanation of format file name. ....	12
<b>2.1.</b> Manipulator of CloPeMa project .....	3
<b>2.2.</b> Identification of arms .....	4
<b>2.3.</b> Description of manipulator .....	4
<b>2.4.</b> Gripper .....	5
<b>3.1.</b> Position of arm with camera.....	8
<b>3.2.</b> Suggestion of movements perpendicular to optical axis ....	9
<b>3.3.</b> Suggestion of movements along to optical axis.....	9
<b>5.1.</b> Depth Map .....	15

# Chapter 1

## Introduction

### 1.1 Motivations

This bachelor thesis is part of Clothes Perception and Manipulation project (CloPeMa, 2012-2015) funded by the European Commission. CloPeMa is research project which aims to advance the state of the art in the autonomous perception and manipulation of fabrics, textiles and garments. The CLoPeMa robot will learn to manipulate, perceive and fold a variety of textiles [1].

### 1.2 Goals

The whole CloPeMa project is based on the manipulation of clothes (garments). Simplified dynamic physical model of real garment should be useful for these manipulations e.g. for simulating movement or collision detection. Creating virtual model of garment depend on its parameters. This thesis has goal to design method of measurement and extraction of image features for obtaining parameters which will lead to construct the model.

### 1.3 The State of the Art

The main sphere of using dynamic simulation of garment is computer graphic. These simulations are mainly for a realistic look, but not for real dynamic physical behavior of garment [2] (including modern method of simulating [3–4]). A lot of simulators and methods have been developed in the field of simulation models of garments (especially fabrics) [5–11]. Some of these tools or methods of simulation use for construct model from a real parameters of garments (fabrics) obtained e.g. by KESF etc. [9, 11]. But simulation of garment is not a point of this work.

In the science and industry exist several measuring techniques which is used to find elementary parameters of fabrics e.g. KESF, FAST or FAMOUS. Kawabata's Evaluation System of Fabric (KESF) is used to get the mechanical properties of the clothes. KESF contains a several equipments for measure these properties. KESF was developed for mass-spring method. The method need a piece of fabric (size depends on the current implementation) for the measurement. On this sample is applied a force in the different directions and ways (depends on current physical property). The KESF produces curves depending on the applied force. The Kawabata instruments test with high accuracy: compression, pure bending rigidity, roughness, shear, surface friction and tensile [12–14].

Very similar to the Kawabata's System is the most popular commercial system - Fabric Assurance by Simple Testing (FAST). Both systems were designed to measure fabric mechanical properties at low-stress level, but both systems use different testing principles. KESF system measure deformation and recovery behaviour while FAST

The Fabric Automatic Measurement and Optimisation Universal System (FAMOUS) is faster method of "manual" measurement. A complete suite of measurement take less than five minutes [13].

There are also methods of estimating cloth simulation parameters based on extraction features from video. [17] has developed the method based on the fabric projected a structured light pattern of horizontal stripes. A perceptually motivated metric based on matching between folds is used to compare video of real cloth with simulation. This metric compares two video sequences of cloth and returns a number that measures the differences in their folds [17].

- Zmínit a více rozepsat použití Mocapu [18]

Therefore, we propose which parameters we will need for build a simple dynamic physical model and we propose easiest way to obtain these parameters. We think that for such a simplified model, the parameters are well estimated from a moving garment, for which this model we want to build. This movement will cause the robot and we will capture the movement according to available equipment of robot (chap. 2.1), thus we use the RGB camera and rangefinder.



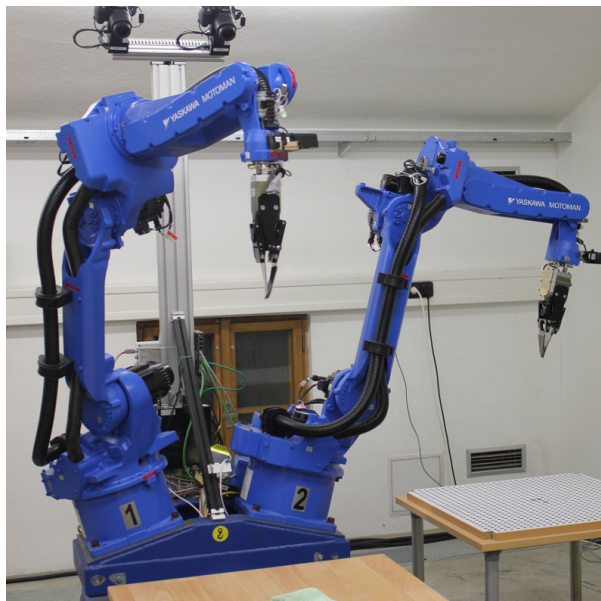
# Chapter 2

## Description of Workplace and of the Software

### [sec:workplace] 2.1 Workplace

#### 2.1.1 Manipulator

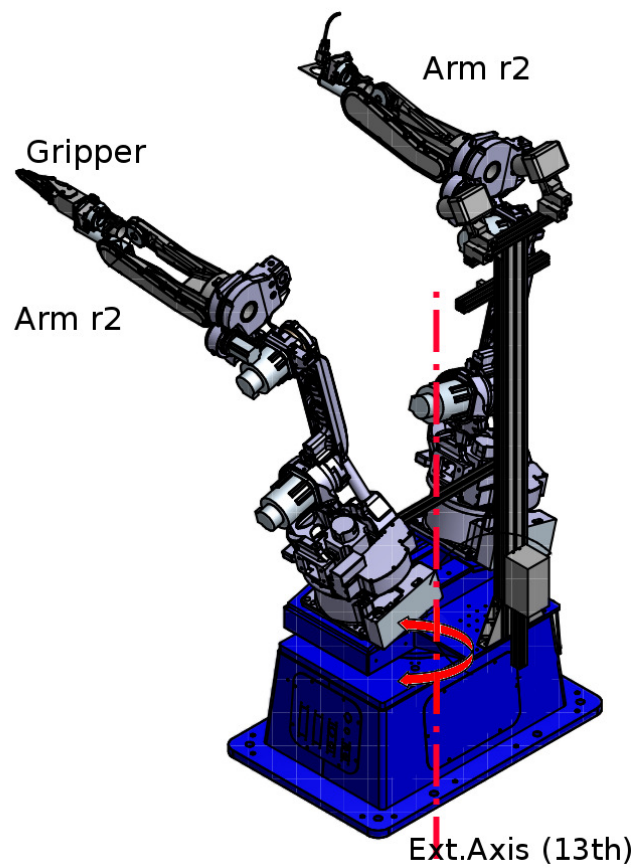
The base is composed of two robotic manipulator arm Motoman MA1400. First arm is called as **r1** (or also appears like **R1**). Second arm is similarly marked **r2** (**R2**). The arms **r1** and **r2** are placed on the turntable. The turntable is rotated about an axis known as **external axis** (or **Ext.** or possibly as axis **13**). Location of arms and rotating around the **Ext.** axis can be better seen from (figure 2.2).



[fig:cturobot]

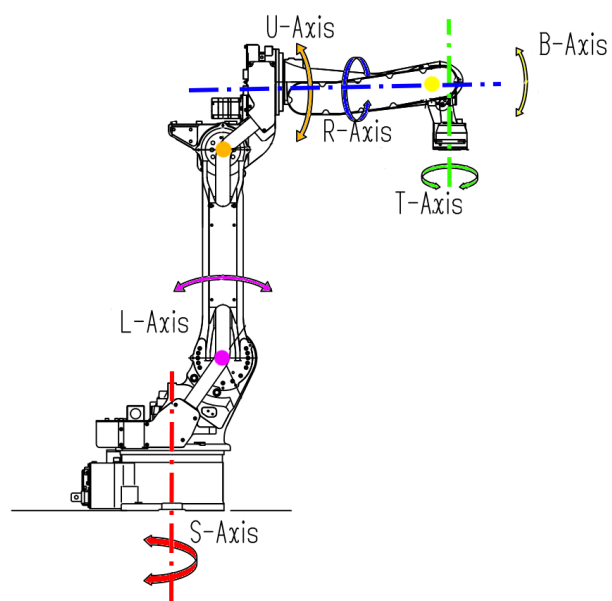
**Figure 2.1.** Manipulator of CloPeMa project location at CTU

Each arm of manipulator has 6 rotation axes. The axes are labeled according to the manufacturer with the letters **S**, **L**, **U**, **R**, **T** and **B** (figure 2.3). This is description of single the arm of robot. Numeral is added to identify the arms e.g. **S** axis located on the arm **r1** will be called **S1**, etc. Similarly to the designation of arms we can meet even using small letters (eg.: **s1**).



[fig:motomanAndTable]

**Figure 2.2.** Identification of arms and location of external axis.

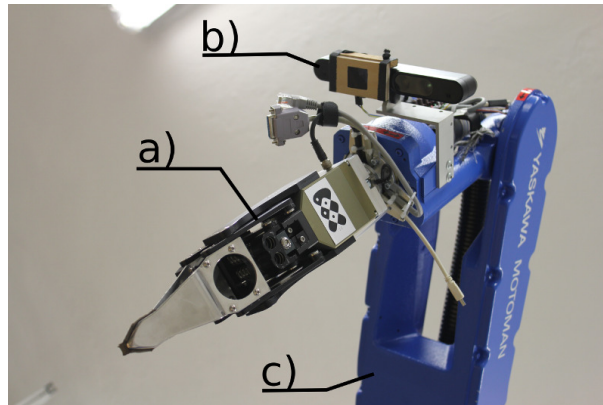


[fig:motomanAxis]

**Figure 2.3.** Description of robotic arm Motoman MA1400 - axis.

### 2.1.2 End Effector

Each of arms `r1` and `r2` are ended with electrically controlled grippers (figure 2.4). Grippers are designed for grasping garment. The prototype of gripper was developed especially for CloPeMa project by the University of Genoa. The gripper is composed of two supple fingers. Supple fingers are used for lifting garments from the table. Gripper has a tactile sensor at the "finger tips" to sense the garment material using little rubbing motions between the "gripper finger" [1]. **použit SOFT místo SUPPLE?**



[fig:gripper]

**Figure 2.4.** End effector (gripper). a) gripper, b) sensor Asus Xtion, c) end of arm on which the gripper is mounted.

[secc:camera]

### 2.1.3 Sensors

The robot has been setup with a variety of sensors:

#### ■ Robot Binocular-Vision Head

- The robot head comprises two Nikon D5100 DSLR cameras. These are mounted on two pan and tilt units. The head provides the robot system with high resolution 3D points clouds [1].

#### ■ Photometric Stereo Gripper-Mounted Sensor

- There is a small scale close range stereo-pair camera sensor. The sensors capture at 1280×800 px resolution and has software support to do 3D reconstruction of close-range garment surface [1].

#### ■ Wrist Force-Torque Sensor

- ATI Mini45 FT six-axis force/torque sensor is integrated in the wrist of one gripper. It is used to sense for contact of the gripper with table and for feedback for the robot system when stretching out a held-up piece of clothing [1].

#### ■ Xtions

- Asus Xtion Pro Live sensor is able to record RGB images and depth maps. The robot has two to three these sensors — one on the each arm [1].

Xtion sensor is for our purposes the most suitable. Xtion has sufficient resolution of RGB image and depth map. In addition, Xtion has a sufficient number of frames per second (compared to slower stereo-pair). Xtion mounted on the arm `r1` is called `xtion1` and Xtion mounted on the arm `r2` is called `xtion2`. Position of cameras is shown in figure 2.4.

## 2.2 Software

Robot is operated using Robot Operating System (ROS). ROS is an open-source system. ROS is not an operating system in the traditional sense of process management and scheduling. Rather, it provides a structured communications layer above the host operating systems of a heterogenous compute cluster [19]. In CloPeMa project is used Ubuntu (Debian-based Linux OS) as a host operating system.

[secc:rosintro]

### 2.2.1 Robot Operating System

A system built using ROS consists of a number of processes, potentially on a number of different hosts, connected at runtime in a P2P topology. The fundamental concepts of the ROS implementation are **nodes**, **messages**, **topics**, and **services**.

**Nodes** are processes that perform computation. ROS is designed to be modular. A system is typically comprised of many nodes. In this context, the term "node" is interchangeable with "software module". Nodes communicate with each other by passing messages. A **message** is a strictly typed data structure. Standard primitive types (integer, floating point, boolean, etc.) are supported. Arrays of primitive types and constants are supported too. Messages can be composed of other messages, and arrays of other messages, nested arbitrarily deep. A node sends a message by publishing it to a given **topic**. A node that is interested in a certain kind of data will subscribe to the appropriate topic. There may be multiple concurrent publishers and subscribers for a single topic, and a single node may publish and/or subscribe to multiple topics. In general, publishers and subscribers are not aware of each others existence [19].

Although the topic-based publish-subscribe model is a flexible communications paradigm, its "broadcast" routing scheme is not appropriate for synchronous transactions, which can simplify the design of some nodes. In ROS, we call this a **service**, defined by a string name and a pair of strictly typed messages: one for the request and one for the response [19].

In the ROS are designed a large number of tools e.g. for get and set configuration parameters, for plotting or visualisation. For this project is important a **roscat tool**. This is basically a set of tools for recording from and playing back to ROS topics [20]. With help of this tool we can record **all or just some** chosen topics. **The chosen topics are passed like parameters to the roscat tool. The roscat tool records all published messages from chosen topics, including timestamp. The tool stores timestamped messages to a specially formatted \*.bag file (also bagfile or roscat-file). The roscat tool can later replay these messages from roscat file too.**

# Chapter 3

## Way of getting data

[sec:requirements]

### 3.1 Goals of experiment

The requirement on the experiment is to obtain mathematical features by which could be used to estimate the parameters of the dynamic physical model of garment. These features we determine by tracking hanging garment. Movement of hanging garment will be causes the movement of the manipulator gripper that holds garment. Based on the sensors that we have available, we have chosen:

- simplest movement, which could give us the necessary data. Data that could be used to obtain the features of the dynamic model of garment. This movement is the movement of garment in the plane, ideally excited by moving gripper of a garment in a straight line (line segment),
- two types of motion capturing:
  - a) with standart RGB video camera capturing a silhouette of garment against the constant background when garment is moving **perpendicular to the optical axis**,
  - b) with rangefinder capturing when garment is moving **along the optical axis**.

### 3.2 Realisation

Both arms of manipulator are used for the experiment. One arm causes a movement of garment that is held by the gripper of this arm. Xtion sensor (2.1.3), located on the second arm, is used for capturing the movement.

Movement along a straight line or line segment (chap. 3.1) requires synchronous movement of the all axes. This movement is ensured thus that the end of gripper slide on the selected points on the line segment. If robot is in the mode "controlled by ROS", we found that the dynamics of the manipulator is not fast enough to perform the desired movement of the gripper with garment necessary speed.

However, it is possible to achieve the required speed when the motion is based on a movement of a one axis. The synchronous movement of all axes was replaced by a motion a one axis, which may not be synchronous with the other. Thus the movement of gripper along line segment is approximated by moving the gripper on the part of the circle.

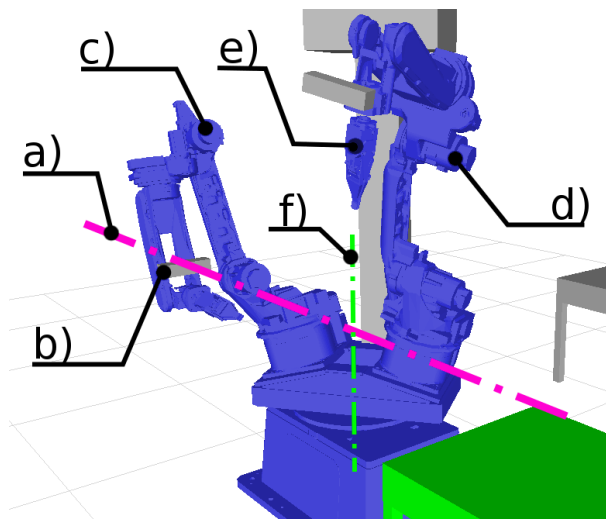
We decided capture the movement of garment in two ways. We use both possibilities of Xtion sensor — capturing RGB images and depthmaps too. When garment is moving perpendicular to the optical axis, will be captured RGB images. When garment is moving along the optical axis, will be captured depthmaps. We need background subtraction for processing RGB images. Background subtraction needs RGB image without garment on foreground.

Another limitation is the spatial limitation, such that it is not possible to place the camera xtion in the appropriate position to capture RGB images (ie, the position where

the gripper with garment moves perpendicular to the optical axis) and then the camera `xtion` move to position suitable for capturing depth maps (ie, the position where the gripper with garment moves along the optical axis). These restrictions are solved via camera `xtion` position (ie the position of the arm with the camera) which is fixed in the same position for record RGB videos as well as for sensing depth maps. Instead, the arm with garment makes a move of gripper with two different ways so that the movements fulfilled the conditions for sensing with each sensors (perpendicular position vs. along the optical axis). **OBRÁZEK - Ale jaký?**

### [sec:caprgb] 3.3 Capturing of RGB

#### [secc:extrgb] 3.3.1 External Axis



[fig:Opt0sa]

**Figure 3.1.** Position of arm with camera. a) optical axis of camera `xtion1`, b) camera `xtion1`, c) arm `r1`, d) arm `r2`, e) gripper of arm `r2`, f) ext. axis.

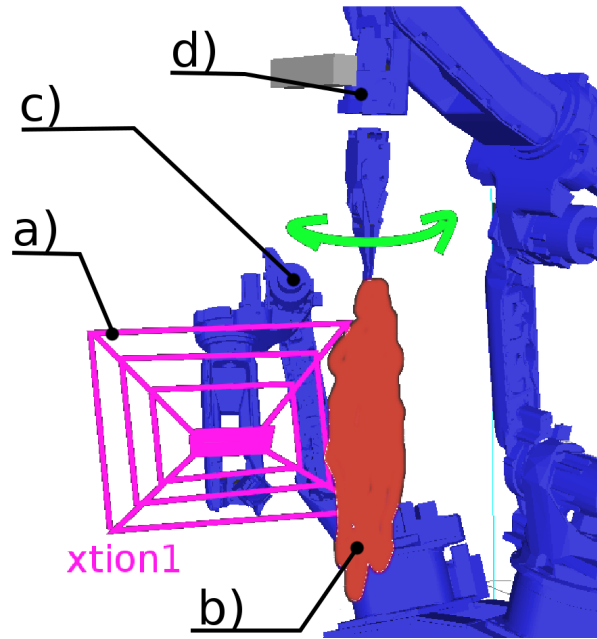
Ext. axis (axis 13) is rotated so that in the background of captured garment is as least as possible disturbing objects. The best is single color flat surface. The ext. axis is stationary during the experiment.

#### [secc:r1rgb] 3.3.2 Arm with Xtion Sensor

The record is captured with camera `xtion1` mounted on the arm `r1`. The arm `r1` moves into position where the optical axis of the camera heads horizontally. Simultaneously is the optical axis of the camera oriented towards arm `r2` (figure 3.1 ). The arm `r1` is stationary during the experiment.

#### 3.3.3 Arm with Garment

Garment is held by gripper mounted on arm `r2`. The arm `r2` is in a height at which camera `xtion1` can capture movement of garment. The arm `r2` is in a position which it can perform movement required for the experiment (chap. 3.1). The arm `r2` makes movement so as garment moved perpendicularly to the optical axis. The arm `r2` makes a desired movement with the garment so that it rotates about an axis B certain angle and will return back to initial position. For better describe of the movement is movement mooted in the figure 3.2.



[fig:kolmoOpt0sy]

**Figure 3.2.** Suggestion of movements of gripper with garment perpendicular to optical axis. a) mooted of field of vision of camera xtion1, b) garment, c) arm r1, d) arm r2.

[subsec:refRGB]

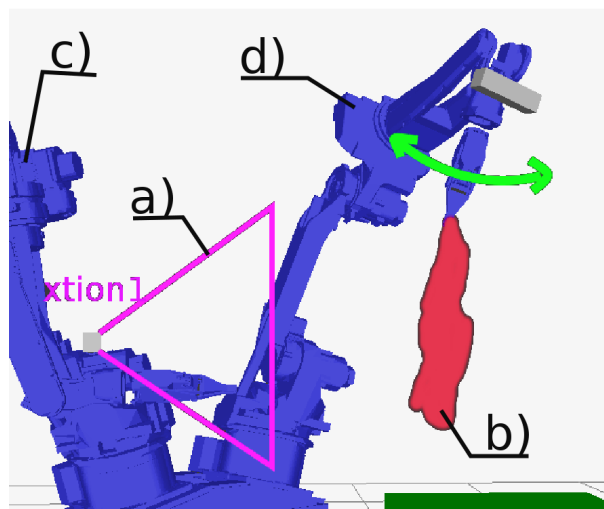
## 3.4 Capturing of Depth maps

### 3.4.1 External axis

Ext. axis (axis 13) is rotated as in the case of capturing of RGB (chap. 3.3.1).

### 3.4.2 Arm with Xtion sensor

The arm r1 is into same position as in case of capturing of RGB (chap. 3.3.2).



[fig:rovnoOpt0sy]

**Figure 3.3.** Suggestion of movements of gripper with garment along to optical axis. a) mooted field of vision (xtion1 sensor), b) garment, c) arm r1, d) arm r2.



### ■ 3.4.3 Arm with Garment

Garment is held by gripper mounted on arm **r2**. The arm **r2** is in a height at which camera **xtion1** can capture movement of garment. The arm **r2** is in a position which it can perform movement required for the experiment (chap. 3.1). The arm **r2** makes movement so as garment moved along to the optical axis. The arm **r2** makes a desired movement with the garment so that it rotates about an axis **R** certain angle and will return back to initial position. For better describe of the movement is movement mooted in the figure 3.3.

## ■ 3.5 Capturing Background Image

This position is used for capture a reference image of background, for improve results of the experiment. The captured image is used for filtering background (background subtraction) from RGB image. More to background subtraction is deal in chapter ??.

### ■ 3.5.1 External axis

Ext. axis (axis 13) is rotated as in the case of capturing of RGB (chap. 3.3.1).

### ■ 3.5.2 Arm with Xtion sensor

The arm **r1** is into same position as in case of capturing of RGB (chap. 3.3.2).

### ■ 3.5.3 Arm with Garment

The reference image of background is captured that the arm **r2** (in which gripper is **not** held garment in this case) change position so that the arm **r2** is completely out of captured area of **xtion1**. In this position is performed the capture of background and the arm **r2** with the garment was returned to the position of measurement.



## Chapter 4

### Data Structure

For the purpose of the experiment is good data processed offline. It is therefore important to store the measured data to data structure and then in MATLAB calculate the parameters that are important for the experiment (chap. 5). If the results of experiment are good and quick, will be the calculation in the future transformed from MATLAB to the ROS.

#### 4.1 Format of Recorded Data

Data is stored by using rosbag tool (chap. 2.2.1) in the format `.bag` to the folder set in the `local_options.py` file <sup>1)</sup>.

#### [sec:topics] 4.2 Topics

The CloPeMa robot can produce over two hundred topics (chap. 2.2.1) when running. Due to the saving disk space and capacity of the transmission channel are recorded only topics which are important to the evaluation of the experiment. Selected topics are set in `topics.txt` <sup>2)</sup> and contains these chosen topics:

```
/joint_states
/tf
/xtion1/depth/camera_info
/xtion1/depth_registered/camera_info
/xtion1/rgb/camera_info
/xtion1/depth/image_raw
/xtion1/rgb/image_raw
/feedback_states
```

#### 4.3 Measured Data Set of the Garments

##### 4.3.1 Structure of Data Set

**Zde bude popsána datová sada a kde bude uložena**

##### 4.3.2 Format of Names of Recorded Files

Recorded files are stored under different names accord to the form `name_speed_AX.bag` (table 4.1).

##### 4.3.3 Description of the Garments

**Zde bude výčet některých použitých látek jako hmotnosti, rozměry ...**

<sup>1)</sup> `path_to_workspace/clopema_cvut/clopema_collect_model_data/src/local_options.py`

<sup>2)</sup> `path_to_workspace/clopema_cvut/clopema_collect_model_data/matlab/topics/topics.txt`

name	chosen file name by user
speed	chosen speed of manipulator
A	axis, which was executed movement <b>R</b> or <b>B</b> (figure 2.3)
X	number of topics file

[explanation]

**Table 4.1.** Explanation of format file name.

# [chap:dataproc] Chapter 5

## Data Processing

- U všech obrázku níže udělat alternativu (lépe dvě) a tu vložit do přílohy a odkázat na ní

### 5.1 Load Data to the MATLAB

- Popis + použitý kód

### 5.2 Extraction of Features from RGB

- Pohovořit v kostce, co očekávám, že dostanu z těchto dat a stručně, jak budu postupovat.
- Obrázek syrových dat 4 pcs

#### 5.2.1 Rectification of RGB

- Popsat, jak opravím RGB snímek + obrázek

#### 5.2.2 Filtering Background by Use Reference Image

- Způsob filtrace proti pozadí - napsat vzorec
- Popsat i použité morphologické operace pro zkvalitnění siluety (možná vlastní secc)
- Obrázek siluety 4 pcs

#### 5.2.3 Finding End of Gripper

- Popsat, jak naleznou oblast, kterou opisuje chapadlo při hýbání s látkou a jak z tohoto pohybu naleznou konec chapadlo v obraze
- Obrázek s vyznačenou kružnicí a bodem jako koncem gripperu

#### 5.2.4 Finding Central Curve of Garment

- Napsat, jak hledám osu bramboroidu
- Popsat zde zavržené metody
  - Kostra grafu + obrázky + proč jsem to nepoužil
  - Střed dle y osy + obrázek + proč jsem to nepoužil
- Obrázky postupného nalezení osy bramboroidu (při aproximaci udělat více obrázků)

## ■ 5.2.5 Finding Mathematical Features from RGB

- Popsat, jak z osy bramboroidu naleznou body, které předávám jako výstup
- Obrázky se siluetou a v ní s body

## 5.3 Extraction of Features from Depth Map

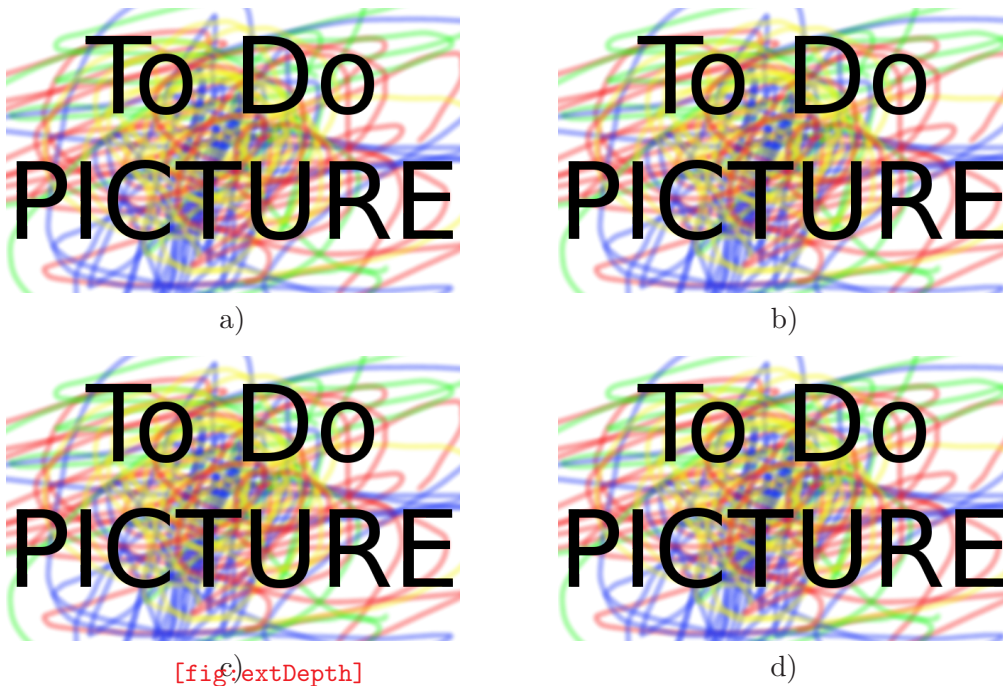


Figure 5.1. Depth Map.

- Pohovořit v kostce, co očekávám, že dostanu z těchto dat a stručně, jak budu postupovat.
- Obrázky surových dat - depthmap

### 5.3.1 Rectification of Depth Map to 3D points

- Popsat způsob, napsat vzorec
- obrázky předělaného depthmap do 3D points

### 5.3.2 Filtering by Depth of Area

- Jak filtruji dle vzdálenosti pouze tak, aby mi zůstala hýbající se látka
- Obrázek filtrovaný dle hloubky

### 5.3.3 Finding Points

- Nalezení gripperu
- Vytvoření pole bodů s osou procházející gripperem
- Nápady:
  - snímat body v polí rovnoměrně
  - snímat body ve sloupci dle osy
  - snímat celé tlusté řádky
- Přiřadit obrázky

### ■ 5.3.4 Finding Mathematical Features from Depth Map

- Nalezení a vyplivnutí bodů ke zpracování

## Chapter 6

### Results

- Provést měření typu: 5x jsem naměřil po sobě stejným způsobem stejnou látku (provést u více látek) a srovnat, zdali jsou si výsledky podobné.
- Naměřit více různých látek a zjistit, zda-li jsou si látky podobné (neměli by být).
- Provést pro RGB i DepthMap data
- Vyrobit a vložit grafy

## Chapter 7

### Discussion

- Diskutovat použitelnost
- Napsat, co by se dalo zlepšit, případně i jak
- Podařilo se mi:
- Vyšlo mi:
- Funguje to tak a tak:
- Je to tak a tak rychlé:
- Je to tak a tak přesné:
- Tady jsou typické případy, kde to zafungovalo:
- Tady jsou typické případy, kdy to selhalo:
- Nejvíce si cením:
- Uvést nápady, které jsem nestihl realizovat jako možné pokračování
- Případné vynechání této kapitoly a diskutování v závěru

**do 11.5.**



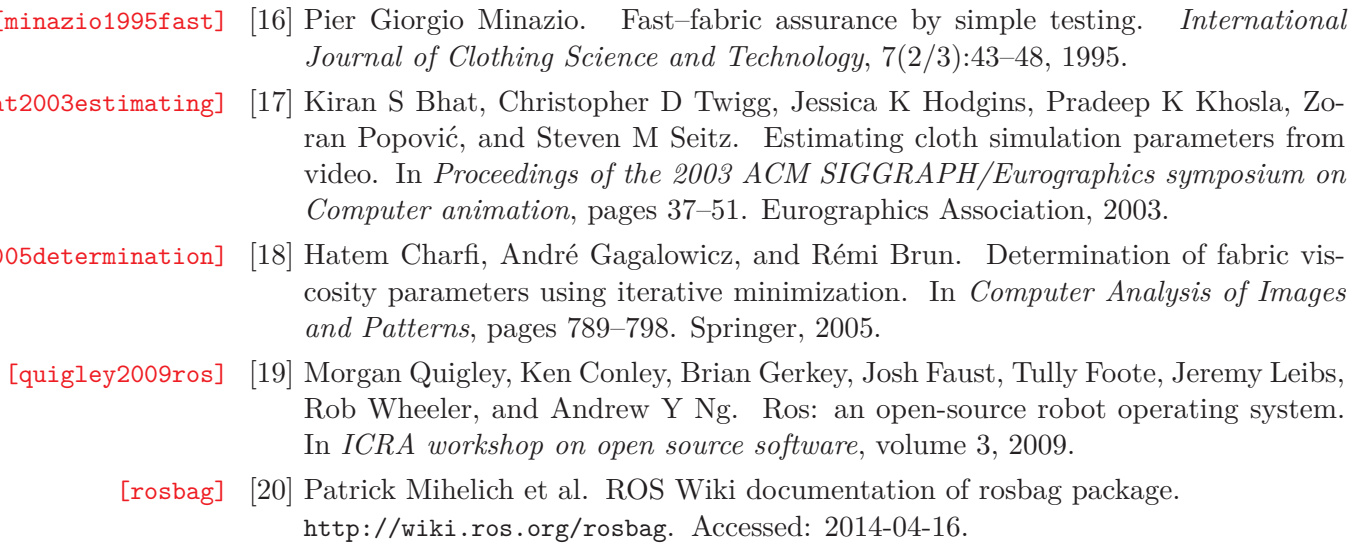
## Chapter 8

### Conclusion

- V práci je: ...
  - Hlavní úspěchy jsou: ...
  - Důležitými výsledky jsou: ...
  - Podařilo se: ...
  - Za nejdůležitější výsledek považuji:
  - Možnost vynechání kapitoly DISCUSSION a uvedení jejího obsahu sem
  - Pohled do budoucna (přeformulovat, změnit, rozšířit):
    - V případě, že se ukáže tento způsob sběru dat a tvorba modelu (odkaz na jinou bc.práci) užitečnou, bylo by dobré naprogramovat celý tento postup i s tvorbou modelu v operačním systému ROS, aby nebylo třeba dalších výpočetních nástrojů (MATLAB).
  - Rekapitulovat naplnění všech bodů práce
- do 11.5.**

## References

- [clopema] [1] CloPeMa clothes perception and manipulation. <http://clopema.eu/>. Accessed: 2014-03-20.
- [choi2005research] [2] Kwang-Jin Choi and Hyeong-Seok Ko. Research problems in clothing simulation. *Computer-Aided Design*, 37(6):585–592, 2005.
- [bender2013adaptive] [3] Jan Bender and Crispin Deul. Adaptive cloth simulation using corotational finite elements. *Computers & Graphics*, 37(7):820–829, 2013.
- [lee2013automatic] [4] Yongjoon Lee, Jaehwan Ma, and Sunghee Choi. Automatic pose-independent 3d garment fitting. *Computers & Graphics*, 37(7):911–922, 2013.
- [terzopoulos1987elastically] [5] Demetri Terzopoulos, John Platt, Alan Barr, and Kurt Fleischer. Elastically deformable models. In *ACM Siggraph Computer Graphics*, volume 21, pages 205–214. ACM, 1987.
- [breen1994predicting] [6] David E Breen, Donald H House, and Michael J Wozny. Predicting the drape of woven cloth using interacting particles. In *Proceedings of the 21st annual conference on Computer graphics and interactive techniques*, pages 365–372. ACM, 1994.
- [volino1995versatile] [7] Pascal Volino, Martin Courchesne, and Nadia Magnenat Thalmann. Versatile and efficient techniques for simulating cloth and other deformable objects. In *Proceedings of the 22nd annual conference on Computer graphics and interactive techniques*, pages 137–144. ACM, 1995.
- [baraff1998large] [8] David Baraff and Andrew Witkin. Large steps in cloth simulation. In *Proceedings of the 25th annual conference on Computer graphics and interactive techniques*, pages 43–54. ACM, 1998.
- [eischen2000continuum] [9] J Eischen and Roberto Bigliani. Continuum versus particle representations. *Cloth modeling and animation*, pages 79–122, 2000.
- [choi2005stable] [10] Kwang-Jin Choi and Hyeong-Seok Ko. Stable but responsive cloth. In *ACM SIGGRAPH 2005 Courses*, page 1. ACM, 2005.
- [luble2008simulation] [11] Christiane Luble and Nadia Magnenat-Thalmann. The simulation of cloth using accurate physical parameters. *CGIM 2008, Innsbruck, Austria*, 2008.
- [kawabata1982objective] [12] Sueo Kawabata, R Postle, and Masako Niwa. *Objective specification of fabric quality, mechanical properties and performance*. Textile Machinery Society of Japan, 1982.
- [stylios2005new] [13] George K Stylios. New measurement technologies for textiles and clothing. *International Journal of Clothing Science and Technology*, 17(3-4):3–4, 2005.
- [ancutienė2010relationship] [14] Kristina Ancutienė, Eugenija Strazdienė, and Anastasija Nesterova. The relationship between fabrics bending rigidity parameters defined by kes-f and fast equipment. *Materials Science= Medžiagotyra*, 16(4):346–352, 2010.
- [stylios1991textile] [15] George Stylios. *Textile objective measurement and automation in garment manufacture*. Ellis Horwood Ltd, 1991.







## Appendix **A** Specification

## Appendix B

### Content of included DVD

- Databaze látek
- Získané výsledky z nich
- Natočená videa
  - Video z processingu - různé stupně a různé látky
  - Video z pracoviště - sběr dat
- Tato práce
- Všechny scripty
- (Manuál na sběr dat CZ)
- ReadMe

**do 11.5.**

## Appendix C

### Abbreviations

1D,2D,3D,...	One Dimension, Two Dimensions, Three Dimensions, ...
CTU	Czech Technical University in Prague.
KESF	The Kawabata Evaluation System for Fabric is used to measure the mechanical properties of fabrics.
FAMOUS	Fabric Automatic Measurement and Optimisation Universal System.
FAST	Fabric Assurance by Simple Testing.
OS	Operating System.
P2P	A Peer-To-Peer it's type of decentralized network.
PLMS	Pucker Laser Measurement System.
RGB	The additive color model of using Red, Green and Blue colors of lights to create or capture the required color.
ROS	The Robot Operating System - an open source system is used for control robots.
URI	Uniform Resource Identifier.



## Appendix **D**

### Brief Manual to Get Data Manually

- Přeložit návod z CZ do EN  
do 11.5.