Robust Machine Vision for Service Robotics

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To my mother
(Pentru mama mea)
Marmandiu Maria

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Bremen, April 2010 Sorin M. Grigorescu

Abstract

In this thesis the vision architecture ROVIS (*RObust machine VIsion for Service robotics*) is suggested. The purpose of the architecture is to improve the robustness and accuracy of visual perceptual capabilities of service robotic systems. In comparison to traditional industrial robot vision where the working environment is predefined, service robots have to cope with variable illumination conditions and cluttered scenes. The key concept for robustness in this thesis is the inclusion of feedback structures within the image processing operations and between the components of ROVIS. Using this approach a consistent processing of visual data is achieved.

Specific for the suggested vision system are the novel methods used in two important areas of ROVIS: definition of an image ROI, on which further image processing algorithms are to be applied, and robust object recognition for reliable 3D object reconstruction. The ROI definition process, build around the well known "bottom-up top-down" framework, uses either pixel level information to construct a ROI bounding the object to be manipulated, or contextual knowledge from the working scene for bounding certain areas in the imaged environment. The object recognition and 3D reconstruction chain is developed for two cases: region and boundary based segmented objects. Since vision in ROVIS relies on image segmentation on each processing stage, that is image ROI definition and object recognition, robust segmentation methods had to be developed. As said before, the robustness of the proposed algorithms, and consequently of ROVIS, is represented by the inclusion of feedback mechanisms at image processing levels. The validation of the ROVIS system is performed through its integration in the overall control architecture of the service robot FRIEND. The performance of the proposed closed-loop vision methods is evaluated against their open-loop counterparts.

Kurzfassung

In der vorliegenden Dissertation wird das Bildverarbeitungsrahmenwerk ROVIS (*RObust machine VIsion for Service robotics*) vorgestellt. Dieses Rahmenwerk dient zur Verbesserung von Robustheit und Genauigkeit der visuell wahrnehmenden Fähigkeiten von Servicerobotiksystemen. Im Vergleich zu traditionellen Industrierobotern, bei denen die Arbeitsumgebung vordefiniert ist, müssen Serviceroboter variierende Beleuchtungsbedingungen und komplexe Umgebungen meistern. Das Schlüsselkonzept für die Robustheit in dieser Dissertation ist der Einsatz von Rückkopplungsstrukturen in den Bildverarbeitungsalgorithmen und zwischen den einzelnen ROVIS-Komponenten. Unter Verwendung dieses Ansatzes wird eine konsistente Verarbeitung der visuellen Daten erreicht.

Charakteristisch für das vorgeschlagene Bildverarbeitungssystem sind die neuartigen Methoden, die in zwei wichtigen Bereichen von ROVIS genutzt werden: die Definition von ROIs (Region Of Interest) im Bild, auf die dann weitere Bildverarbeitungsalgorithmen angewandt werden können, und die robuste Objekterkennung für zuverlässige 3D-Rekonstruktion. Das Verfahren zur Definition der ROI, das um das allgemein bekannte "bottom-up top-down" Rahmenwerk errichtet wurde, verwendet entweder Pixelinformationen zur Konstruktion einer ROI, die das interessierende Objekt enthält, oder kontextabhängige Erkenntnisse aus der Szene für die Begrenzung bestimmter Bereiche der visualisierten Umgebung. Die Objekterkennung und 3D-Rekonstruktion wurde für zwei Fälle entwickelt: bereichs- und kantenbasierte Erkennung von Objekten. Weil die Bildverarbeitung in ROVIS in jeder Verarbeitungsphase, d.h. bei der ROI-Definition und der Objekterkennung, auf Bildsegmentierung beruht, mussten robuste Segmentierungsalgorithmen entwickelt werden. Wie bereits erwähnt, wird die Robustheit der vorgestellten Verfahren und damit die Robustheit von ROVIS durch den Einsatz von Rückkopplungsstrukturen auf der Ebene der Bildverarbeitung erreicht. Eine Bestätigung der Güte von ROVIS ist durch die Integration im Steuerungsrahmenwerk des Serviceroboters FRIEND gegeben. Die Effizienz der vorgestellten visuellen Rückkopplungsmethoden wird durch einen Vergleich mit den zugehörigen Verfahren, die offene Regelkreise verwenden, bewertet.

Contents

1 Introduction **2**

1.1 Related work and contribution of the thesis 5

1.2 Organization of the thesis 9

2 Object recognition and 3D reconstruction in robotics **10**

2.1 Open-loop vs. closed-loop image processing 10

2.2 Stereo image acquisition 13

2.2.1 Hardware components 13

2.2.2 Image representation 16

2.3 Image pre-processing 17

2.4 Image segmentation 19

2.4.1 Open-loop image segmentation 19

2.4.2 Closed-loop image segmentation 22

2.5 Feature extraction 25

2.6 Classification 28

2.7 3D reconstruction 29

3 ROVIS machine vision architecture **31**

3.1 FRIEND I and II vision systems 31

3.2 The ROVIS concept 33

3.2.1 Classification of objects of interest 34

3.2.2 ROVIS block diagram 36

3.2.3 Interest image areas in ROVIS 39

3.2.4 Robustness in ROVIS through feedback mechanisms 40

3.3 Architectural design 41

3.3.1 Software architecture 42

3.3.2 Execution of vision algorithms 43

3.4 ROVIS integration in a service robotic system 45

3.4.1 ROVIS hardware components in FRIEND 46

3.4.2 Support scenarios 48

3.4.3 Overall robot control architecture 49

3.4.4 Functional analysis of workflow 50

4 Robust image segmentation for robot vision **52**

4.1 Robust region based segmentation 54

4.1.1 Evaluation of color information 54
4.1.2 Closed-loop intensity segmentation 56
4.1.3 Closed-loop color segmentation 61
4.2 Robust boundary based segmentation 67

5 Image Region of Interest (ROI) definition in ROVIS 77
5.1 Definition of the image ROI 77
5.2 Bottom-up image ROI definition through user interaction 78
5.2.1 Problem statement 80
5.2.2 Control structure design 81
5.2.3 Performance evaluation 86
5.3 Top-down image ROI definition through camera gaze orientation 89
5.3.1 Stereo camera head configuration in FRIEND 90
5.3.2 Image based visual feedback control 92
5.3.3 Position based visual control in an intelligent environment 95

6 Object recognition and 3D reconstruction in ROVIS 97
6.1 Recognition of region segmented objects 97
6.1.1 Region based image processing operations 98
6.1.2 Closed-loop improvement of object recognition 102
6.1.3 Performance evaluation of 2D region based object recognition . . . 104
6.2 Recognition of boundary segmented objects 104
6.2.1 Boundary based image processing operations 105
6.2.2 Performance evaluation of 2D boundary based object recognition . . 107
6.3 3D object reconstruction 109
6.4 Performance evaluation of final 3D object reconstruction 111

7 Conclusions and outlook 116

Bibliography 127

A Extremum seeking control 128

B Universal Modeling Language 130

C Genetic algorithms optimization 131

D Sample images from FRIEND support scenarios 133

E List of abbreviations 135

F List of symbols 136