Hans-Dieter Burkhard
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# Multi-Agent Systems and Applications V

5th International Central and Eastern European Conference on Multi-Agent Systems, CEEMAS 2007
Leipzig, Germany, September 2007, Proceedings

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# Preface

The aim of the CEEMAS conference series is to provide a biennial forum for the presentation of multi-agent research and development results. With its particular geographical orientation towards Central and Eastern Europe, CEEMAS has become an internationally recognized event with participants from all over the world. After the successful CEEMAS conferences in St. Petersburg (1999), Cracow (2001), Prague (2003) and Budapest (2005), the CEEMAS 2007 conference took place in Leipzig. The Program Committee of the conference series consists of established researchers from the region and renowned international colleagues, showing the prominent rank of CEEMAS among the leading events in multi-agent systems.

In the very competitive field of agent-oriented conferences and workshops, (such as AAMAS, EUMAS, CIA, MATES) CEEMAS is special in trying to bridge the gap between applied research achievements and theoretical research activities. The ambition of CEEMAS is to provide a forum for presenting theoretical research with an evident application potential, implemented application prototypes and their properties, as well as industrial case studies of successful (or unsuccessful) agent technology deployments. This is why the CEEMAS proceedings provide a collection of research and application papers. The technical research paper section of the proceedings (see pages 1–290) contains pure research papers as well as research results in application settings. The goal is to demonstrate the real-life value and commercial reality of multi-agent systems as well as to foster the communication between academia and industry in this field.

CEEMAS is also very special and unique because it is constantly contributing to building an agent research community. The Program Committee has decided to create a special collection of short papers that provide an opportunity to present ongoing research work with a potential of mature and higher impact research results in the near future. This allows researchers to expose their work for constructive criticism and discuss their projects with other experts in an early phase of their research. On the other hand this provides the audience with fresh, innovative and highly motivating ideas that may deserve further investigation.

The topics of the CEEMAS proceedings cover a wide range of areas such as: abstract and specific agent architectures, methods and modeling approaches for agent-oriented software engineering, agent communication and protocols. CEEMAS also features papers on applications from the field of healthcare, traffic management, learning, software development, game, production management, trade and negotiations.

We received 84 submissions, and each paper was reviewed by at least two independent reviewers or the General Co-chairs. Out of the submitted papers, 29 were accepted as full research papers and 17 as short poster papers.

Many individuals and institutions supported the organization of this conference and made CEEMAS 2007 a high-quality event. Our special thanks go first to the authors and invited speakers for their invaluable and strenuous work and contribution. Also, the work of the Program Committee members who accepted the heavy load of the review of a large number of contributions is gratefully acknowledged. We are especially thankful to the University of Leipzig for their organizational activities.

As a result, the present collection of papers provides a valuable resource for researchers in the field of multi-agent systems and open distributed systems in general.

July 2007

Hans-Dieter Burkhard
Gabriela Lindemann
László Z. Varga
Rineke Verbrugge

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CEEMAS 2007 was co-located with the Software Agents and Services for Business, Research, and E-Sciences (SABRE) set of conferences organized by the Management Information Systems Institute and the Institute for Applied Informatics (InfAI) of the University of Leipzig.

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## Short Papers

# A Multi-agent Approach for Range Image Segmentation

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**Abstract.** This paper presents and evaluates a multi-agent approach for range image segmentation. A set of reactive and autonomous agents perform a collective segmentation by partitioning a range image in its different planar regions. The agents move over the image and perform cooperative and competitive actions on the pixels, allowing a robust region extraction, and an accurate edge detection. An artificial potential field, created around the pixels of interest, ensures the agent coordination. It allows the agents to concentrate their actions around the edges and the noise regions. The experimental results show the potential of the proposed approach for scene understanding in range images, regarding both segmentation efficiency, and detection accuracy.

**Keywords:** Image segmentation, Multi-agent systems, Range image, Agent coordination, Artificial potential field.

## 1 Introduction

Image segmentation consists in assigning the pixels of an image to homogenous and disjoint subsets, providing a compact and convenient description of the image. In range imagery, segmentation algorithms can be divided into two dual categories: edge-based segmentation algorithms and region-based segmentation algorithms. In the first category, pixels that correspond to discontinuities in depth or in surface normals are selected, chained and then used to delimit the regions in the image [6,7]. Region-based methods use geometrical surface descriptors to group pixels, with the same proprieties, in disjoint regions [8,10,3,1]. In both categories, algorithms must deal with noisy and uncertain data.

To overcome this difficulty, some authors have proposed multi-agent systems for 2-D image segmentation. Solutions provided by such systems inherit the advantages of the agent-oriented approach for collective problem solving. In such systems a single agent has a limited perception and limited capabilities, and it is not designed to solve an entire problem. Agents cooperate thus in order to provide a collective solution. Contrary to conventional systems, solutions in multi-agent systems emerge from the collective action of interactive agents [9].

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In this paper, a new multi-agent approach for range image segmentation is presented and discussed. It consists in the use of reactive agents, which move over the image, and act on the visited pixels. While moving over the image, an agent adapts to the planar region on which it moves, and memorizes its proprieties. At the boundaries between regions, the agents will be in competition to align the pixels of the boundaries to their respective regions. The resulting alternative alignment of the boundary pixels preserves the region boundaries against smoothing. Noise regions, which are characterized by small sizes or by aberrant depths (outliers), prevent agents from adapting. So, the pixels on their borders are continuously aligned to the true regions that surround them. After several iterations these regions will entirely disappear.

This work aims to overcome the difficulty related to the local perception around the processed pixel. A pixel is therefore processed according to both its neighborhood, and the agents that visit this pixel. An agent acts on the pixels with more certainty, acquired from its move on large areas on the image regions. The combination of the global information memorized within the agent, and the local information of the image, provides more reliable decisions. We show in this work that despite the simplicity of the model used to represent the image surface, the obtained results are better than those provided by conventional approaches. We believe that interactions between agents provide an alternative way for image segmentation to that of approaches based on complicated and costly models. Extensive experiments have been performed using real images from the ABW database [5]. The obtained results show the high potential of the proposed approach for an efficient and accurate segmentation of range images.

The remainder of the paper is organized as follows: In Section 2, we review some agent-based approaches for image segmentation. Section 3 is devoted to the proposed approach. It describes the behavior of the agents, and shows the underlying collective mechanism to deal with the edge detection and the noise removal. The experimental results are introduced in Section 4, in which we discuss the parameter selection, and we analyze and comment the obtained results. Finally, a conclusion summarizes our contribution.

## 2 Related Work

Several agent-based systems have been proposed to deal with various problems in image analysis and object recognition. In this review we consider only some works that have addressed a solution in image segmentation.

Liu et al. [11] introduce a reactive agent-based system for brain MRI segmentation. Four types of agents are used to label the pixels of the image according to their membership grade to the various regions. In this system, the agents neither interact directly between them nor act on the image. Their actions depend only on their local perception. Nevertheless, each agent is created so that it becomes more likely to meet more homogenous pixels. For the same type of images, Richard et al. [12] propose a hierarchical architecture of situated and cooperative agents. Several types of agents were used. Interaction between agents

in the various hierarchic levels has allowed to deal with the control over the low-level segmentation tasks. However, the system was specially optimized to brain MRI segmentation. The two previous systems can provide correct results because region characteristics are regular in the various brain anatomic parts. In addition, most of the edges in such images are jump edges (at discontinuities of image data), which are easy to detect, compared to roof or smooth edges (edges respectively at normal or curvature discontinuities).

Based on a cognitive architecture, Bovenkamp et al. [2] have developed a multi-agent system for Intra Vascular Ultra Sound (IVUS) image segmentation. They aim to elaborate a high knowledge-based control over the low-level image processing algorithms. In this system, an agent is assigned to every expected object in the image. In this work, the problem of the control over the segmentation algorithms seems to be well resolved. However, no agent or even behavior has been proposed to deal with uncertain and noisy data.

The proposed agent-based systems for image segmentation are specific to image contents. Following a supervised approach, these systems segment images in known and previously expected regions. The system proposed in this paper claims to be general and unsupervised. It aims to segment an image into its different regions by using some invariant surface proprieties. The adaptive and competitive behavior of the agents allows overcoming the constraint related to the restriction of the treatments to the local neighborhood of the pixels.

## 3 Multi-agent Range Image Segmentation

A range image is a discretized two-dimensional array where at each pixel $(x, y)$ is recorded the distance $Z(x, y)$ between the range finder and the corresponding point of the scene. A new image $Z^*$, called plane image is derived from the range image. Each pixel $(x, y)$ of the new image records the tangent plane to the surface at $(x, y)$. The tasks performed by the agents on the plane image are based on the comparison of planes. So, we consider that two planes $ax + by + cz = d$ and $a'x + b'y + c'z = d'$ are equal if they have, according to given thresholds ($Tr_\theta$, $Tr_D$), the same orientation, and the same distance to the coordinate origin. $Tr_\theta$ and $Tr_D$ are respectively the angle and the distance thresholds.

The plane image $Z^*$ is considered as the environment in which the agents are initialized at random positions. An agent checks if it is situated on a planar region, and adapts to this region if it is planar, by memorizing its plane equation. Next, the agent performs actions, which depend on both its state and the state of the pixel on which it is located. At each time $t$, an agent is characterized by its position $(x_t, y_t)$ over the image, and by its ability $A_t$ to act on the encountered pixels. At the beginning of the process, all the agents are unable to alter any pixel of the image. After having been adapted to a planar region, an agent becomes able to modify the first encountered pixel that not belongs to the current region ($A_t$=true). When an agent alters a pixel, it loses its alteration ability ($A_t$=false) and starts again searching for a new planar region. An agent having modified a pixel records in an appropriate two-dimensional array $I$, at $(x_t, y_t)$ the last state