DOAS PROJECT

PROBABILISTIC RESOURCE ALLOCATION IN DISTRIBUTED FUSION SYSTEMS

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Abstract

This project is focusing on resource allocation in Distributed Perception Networks (DPN), an agent-based approach to the fusion of large amounts of heterogeneous information. The emphasis is put on decentralized resource allocation based on multi-agent collaboration.

Introduction

Intelligent process control and decision making in complex systems require adequate situation assessment which, however, requires processing of large amounts of heterogeneous sensory data and information from spatially dispersed sources. This is especially relevant for modern systems, which are becoming increasingly complex. For example, an observation system detecting different types of fires or leakage of very toxic fluids in a chemical factory would make use of very heterogeneous data and information originating from sensors for toxic gases, smoke detectors, infra-red cameras for the detection of flames, instruments measuring pressure and flow in pipeline transporting the toxic fluid, reports of workers, etc. In traditional approaches raw sensory data and other information are processed centrally. However, central sensor data processing and extraction of semantic value is not trivial in modern sensory systems, where we deal with large quantities of data. In general, central approaches suffer from several problems, including inadequate communication and processing capacities, vulnerability to single-point system failures, etc.

Distributed Perception Networks

In order to avoid problems of centralized fusion systems, we developed *Distributed Perception Networks* (DPN), an agent-based approach to fusion of heterogeneous data and information. The agent-based paradigm simplifies solutions for a significant class of complex fusion problems. The DPN approach features rather simple building blocks implemented through agents of different types, which can dynamically be organized into complex data/information fusion systems that can cope with partially unpredictable aspects of the real world.

Each DPN network is a fusion structure which updates belief in a single hypothesis through cooperation of different agents, which in turn can roughly be classified in two types. At the lowest level there are different Sensor agents with direct access to sensors and sensor data interpretation capabilities while at the higher levels Fusion agents use local world models for the information fusion. The local world models in Fusion agents are encoded through Bayesian networks and represent basic world modeling building blocks. The world model required for the fusion can be assembled and updated at runtime on an as-needed basis. Namely, different DPN agents can organize autonomously in complex organizations, i.e. DPN fusion structures. Through such self configuration the local world models of different agents can be integrated into arbitrarily complex world models.

Resource Conflicts

In general, DPN systems must deal with the problem of resource allocation. Namely, there can be several DPN fusion networks running in parallel, monitoring different aspects of a certain environment. Consequently, it can happen that more than one DPN would like to integrate a particular Sensor agent, i.e. an agent with direct a access to the information source. However, in advanced sensing systems, a sensor agent requires setting of different sensing parameters, which will inevitably result in resoure allocation conflicts if each potential user of this agent wants to set different parameters. For example, a data stream from a pan-tilt camera might be used by a DPN monitoring the area to the North while another DPN would like to point the camera to the South.

In order to deal with such situations in an efficient and robust way, we introduce a decentralized approach to resource allocation. In our approach a Sensor agent confronted with conflicting requests determines which fusion network will be granted the rights to change its sensing parameters (e.g. observation direction) and use the data. Such decisions are based on the estimation of the impact the information source would have on the fusion results of each DPN fusion structure that is interested in Sensor agent's information. Basically, in the case of conflicting information requests from several DPN fusion structures, the Sensor agent asks each interested fusion structure to provide an estimate of the impact that the eventually provided information would have on its fusion results. The sensor agent grants the access to its information its sensing parameters to the fusion structure for which the supplied information would have the greatest impact.

Clearly, we need appropriate measures for the evidence impact as well as efficient approaches to determination of such decision criteria. We introduce Cumulative Entropy Change as a measure of the evidence impact, which can be determined through collaboration of the involved DPN Fusion agents. Obviously, such determination shall be as robust and efficient as possible. In particular, we are interested in parametric approaches to belief propagation, which were initially introduced the context of sensitivity analysis of Bayesian Networks. Such approaches are based on the fact that we can express the influence between two arbitrary variables in a BN through a combination of linear functions. In addition, it turns out that such parametric approaches can facilitate efficient collaborative computation of the evidence impact and even belief propagation within a certain class of distributed probabilistic networks.

Project Goals

After refreshing basics in Bayesian Networks and vector algebra, the students will analyze and compare the computational effort of the parametric and the traditional belief propagation approaches.

Based on the mathematical analysis the team will develop and implement an efficient approach to collaborative agent-based determination of the evidence impact on hypothesis nodes in distributed probabilistic networks.

The resulting resource allocation algorithms will enhance the DPN toolbox, a framework which currently implements basic functionality of agent based probabilistic fusion systems.

Tasks

- Install and get familiar with the basic DPN toolbox and Eclipse IDE.
- Study and discuss papers on parametric representation of belief mapping.
- Investigate ways of efficient determination of the belief mapping in distributed probabilistic networks.
- Design and implement DPN components that support decentralized resource allocation and collaborative determination of the evidence impact. The emphasis is put on high-level programming based on the existing DPN toolbox components.
- Present the implemented DPN toolbox components and discuss interesting theoretical as well as design aspects.

Deliverables

- New DPN toolbox components supporting distributed resource allocation.
- Documentation describing the resource allocation components (JavaDoc).
- Final report discussing the theoretical as well as design aspects of the implemented approach to collaborative computation of belief mapping.
- Power Point presentation.

Literature

1. Finn V. Jensen, *Bayesian Networks and Decision Graphs, Statistics for Engineering and Information Science*, Springer, 2001.
2. M. Wooldridge, *Introduction to Multiagent Systems*, John Wiley and Sons, New York, 2002.
3. G. Pavlin, M. Maris, J, Nunnink, *An Agent-Based Approach to Distributed Data and Information Fusion.*