PostDoc Talks

Title: **Learning Situation Models for Providing Context-Aware Services**
By: *Oliver Brdiczka*

This thesis addresses the problem of learning situation models for providing context-aware services in an intelligent environment. First, the notion of context for modeling human behavior in an intelligent environment is motivated and introduced. Context is represented by a situation model describing environment, users and their activities. Two example implementations for the situation model are proposed. A framework for acquiring and evolving different layers of a situation model is then introduced. Several novel learning methods are part of this framework: role detection per entity, unsupervised extraction of situations from multimodal data, supervised learning of situation representations, and the evolution of a predefined situation model with feedback. The situation model serves as frame and support for the different methods, permitting to stay in an intuitive declarative framework. The proposed framework has been implemented and evaluated for an intelligent home environment.

Tilte: **Approximative Techniques for Highly Efficient Simultaneous Localization and Mapping**
By: *Giorgio Grisetti*

The ability to model the environment is an essential pre-requisite for building truly autonomous agents. Learning maps requires to estimate the position of the robot and the map of the environment given a sequence of noisy sensor measurements. In the literature, this problem is known as Simultaneous Localization and Mapping (SLAM). The word "simultaneous" highlights the need to concurrently estimate a joint probability distribution over the potential maps and poses of the robot since both quantities are strongly correlated.

In the last decades, the robotic community has been especially active in this field and several effective solutions have been proposed. Nowadays, solutions to the SLAM problem are able to learn maps of medium size environments. However, the problem of acquiring models of large environments especially in 3D is still an active research problem. Due to the difficulties in performing exact inference on a state space having thousands or even millions of variables, approximative estimation techniques have become popular.

The aim of this talk is to present novel approaches for efficiently determining a solution to the 3D SLAM problem. It uses a combination of stochastic gradient descent and belief propagation to efficiently learn the parameters of the estimated density. It is able to build maps in an on-line fashion by utilizing previously computed solutions. The approach has been used to successfully learn maps from vision data as well as from laser range data. We present large scale maps acquired with an autonomous car.

Title: **Localization and Mapping using Fingerprints of Places**
By: *Adriana Tapus*

The work described here is about topological navigation, more precisely about space representation, perception, localization and mapping. All these elements are needed in order to obtain a robust and reliable framework for navigation. This is essential in order to move in an environment, manipulate objects in it and avoid collisions. The method proposed in this research work is suitable for fully autonomous mobile robots, operating in structured indoor and outdoor environments.

High robustness is necessary to obtain a distinctive and reliable representation of the environment. This can be obtained by combining the information acquired by several sensors

with complementary characteristics. A multimodal perception system that includes the wheel encoders for odometry and two extereoceptive sensors composed of a laser range finder that gives a 360° view of the environment and an omnidirectional camera are used in this work. Significant, robust and stable features are extracted from sensory data. The different features extracted from the extereoceptive sensors (i.e. corners, vertical edges, color patches, etc.) are fused and combined into a single, circular, and distinctive space representation named the fingerprint of a place. This representation is adapted for topological navigation and is the foundation for my whole research work.

One of the major tasks of a mobile robot is localization. Different topological localization approaches based on the fingerprint concept are presented here. Localization on a fingerprint-based representation is reduced to a problem of fingerprint matching. Two of these methods make use of the Bayesian Programming (BP) formalism and two others are based on dynamic programming. They also show how multimodal perception increases the reliability of topological localization for mobile robots. In order to autonomously acquire and create maps, robots have to explore their environment. Several exploration tools for indoor environments are presented: wall following, mid-line following, center of free space of a room, door detection, and environment structure identification.

An automatic and incremental topological mapping system based on fingerprints of places and a global localizer using Partially Observable Markov Decision Processes (POMDP) are proposed. The construction of a topological mapping system is combined with localization, both relying on fingerprints of places, in order to perform Simultaneous Localization and Mapping (SLAM). This enables navigation of an autonomous mobile robot in a structured environment without relying on maps given a priori, without using artificial landmarks and by employing a semantic spatial representation that allows a more natural interface between humans and robots. The fingerprint approach, combining the information from all sensors available to the robot, reduces perceptual aliasing and improves the distinctiveness of places. This fingerprintbased approach yields a consistent and distinctive representation of the environment and is extensible in that it permits spatial cognition beyond just pure navigation. All these methodologies have been validated through experiments. Indoor and outdoor experiments have been conducted over a distance exceeding 2 km. The fingerprints of places proved to provide a compact and distinctive methodology for space representation and place recognition – they permit encoding of a huge amount of placerelated information in a single circular sequence of features. The experiments have verified the efficacy and reliability of this approach.

Title: **Philosophical problems raised by Bayesian network causal inference**
By: *Isabelle Drouet*

Bayesian networks (“BNs” from now onwards) were introduced at the beginning of the 1980s as tools for the representation of uncertainty. Yet it is now clear that they can serve other purposes. More specifically, it has been claimed that algorithms for constructing Bayesian graphs (algorithms IC and IC* by Verma and Pearl, or SGS, PC, PC*, CI and FCI by Spirtes, Glymour and Scheines) may be considered as inferring causal knowledge from probabilistic data. My talk deals with this claim, and more generally with BN causal inference algorithms. One of its main aims is to give an idea of the problems that these algorithms raise for philosophers of science.

These problems massively stem from the fact that the very notion of causal BN involves hypotheses (acyclicity of causality, the causal Markov condition, faithfulness) that are subject to violations. As a consequence, I first set out some of these violations, and examine whether they can be overcome through some tricks – typically the introduction of hidden nodes. It is my contention that these tricks are of no use in the causal inference context that I discuss.

The second part of my talk is concerned with the consequences this has on causal inference as based on BNs. More precisely, I am interested in whether it merely implies that BN causal inference should be reserved for those systems that satisfy the hypotheses involved by the notion of causal BN. I claim that in fact it implies much more than that: strictly speaking, violations of the hypotheses have the consequence that conclusions of BN causal inference are always suspect of being false. This raises the question of whether BN algorithms can in any way contribute to causal inference. As an answer to this last question, I formulate a methodological proposition to the effect of integrating BN algorithms to more traditional causal inference procedures.

Title: **Mobile Robot Localization using vision sensors and active probabilistic approaches**
By: *Emanuele Frontoni*

The use of vision in mobile robotics in one of the main goal of this thesis. In particular novel appearance based approaches for image matching metric are introduced. These approaches are applied to the problem of mobile robot localization.

Similarity measures between robot's views are used in probabilistic methods for robot pose estimation. In this field of probabilistic localization active approach are proposed allowing the robot to faster and better localize. All methods have been extensively tested using a real robot in an indoor environment.

Title: **Bayesian Model for Computational Laban Movement Analysis**
By: *Jörg Rett*

We present the implementation of computational Laban Movement Analysis (C-LMA) using a Bayesian framework.

The research field of computational Human Movement Analysis is lacking a general underlying modeling language, i.e., how to map the features into symbols [1]. With such a semantic descriptor, the recognition problem can be posed as a problem to recognize a sequence of symbols taken from an alphabet consisting of motion-entities. This alphabet would also allow to introduce constraints which make the problem of movement recognition more tractable. It would open the possibility to put more effort on recording and labeling training data. which has happend in the area of Speech Recognition in the past.

Laban Movement Analysis (LMA) has been proven successful in areas where humans are observing other humans' movements like studies of dance and its application to physical and mental therapy [2]. LMA provides a model for observation and description for human movements and a notational system (Labanotation).

To implement LMA in a computer we have chosen a Bayesian approach and the formalism of Bayesian Programming [3]. The framework allows us to model the process, learn and store the dependencies between features and symbols and classify online a movement using the labels of LMA. The full-model is designed through Bayesian networks of smaller sub-models, each one representing a certain aspect of the problem. The classification can be solved by assembling some (or all) sub-models to a full model and asking a question. The connections between the submodels are built through uncertain (soft) evidences that are being exchanged. The Bayesian net can be interpreted as a communication structure with the evidences as its messages.

From the possible applications where C-LMA could be useful like 'Smart Houses', 'Surveillance' and 'Rehabilitation' we have chosen 'Social Robots' to demonstrate the feasibility of our solution. The key-issue social robots are sharing with the other applications mentioned is human-machine interaction. With C-LMA we provide a novel skill to the interaction system to better understand an observed human movement. The technique of

continuous update of a prior belief through observation is reminiscent of human anticipation, while the LMA descriptors allows the expressive content of the movement to be extracted.

Title: **Localisation systems on various platforms and Tricks and Traps in Bayesian Modelling**
By: Cedric Pradalier

This talk will be centered on localisation for robotics application based on Bayesian filters. It will be divided in two parts: a first part will review various implementation of localisation systems on various platforms and try to highlight their specificities and differences. Four platforms will be considered: an industrial truck, an autonomous car, a pedestrian and a submarine.

Having seen these implementations of real systems, the second part of this talk will focus on "tricks and traps" of Bayesian Programming. Examples will demonstrate the effect of range borders and restricted ranges of probabilistic variables. Then we will show how to tune the relative weights of multiple hypothesis in sensor fusion. Finally we will discuss how to express bayesian fusion as a product of distribution and why it can be useful.

Depending on time and student interest, we may discuss the use of the Bayesian programming paradigm to express the notion of self confidence.

Title: **Perception of shapes from motion**
Bayesian combination of optic flow and self-motion
By: *Francis Colas*

Perception can be seen as collecting and confronting various pieces of information in order to understand the environment. One uses many semsory modalities each one consisting of many kind of information. One of these is the optic flow, the displacement of the projected image on the retina.

Optic flow allows for the extraction of part of the geometry of the observed scene. However, it is a very complex problem due to its inverse, ill-posed and uncertain nature.

These issues can be dealt with using the Bayesian programming formalism. It is based on the probabilities, to handle uncertainty and the ill-posed problem, and on Bayes rule, to solve the inversion.

We propose a Bayesian model of the perception of planes from optic flow based on few explicit assumptions. These assumptions are mainly the rigidity, which assumes the observation of a rigid plane is more probable than of a collection of independently-moving points, and the stationarity, which assumes the motion of the plane is more probably small.

We validate our model using five experiments from the literature. For each one, we explain in details the inner workings of our model and the assumptions conditionning a good reproduction of the experimental results. Finally, we show how to adapt our model to an experiment of perception of a corrgated surface by optic flow. We also present a Bayesian model to generate the input of our perception model and generalise the integration of our model into a more complete system.