06231 Abstracts Collection
Towards Affordance-Based Robot Control
— Dagstuhl Seminar —

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Abstract. From June 5 to June 9, 2006, the Dagstuhl Seminar 06231 "Towards Affordance-Based Robot Control" was held in the International Conference and Research Center (IBFI), Schloss Dagstuhl. During the seminar, several participants presented their current research, and ongoing work and open problems were discussed. Abstracts of the presentations given during the seminar as well as abstracts of seminar results and ideas are put together in this paper. Links to extended abstracts or full papers are provided, if available. Additionally, papers related to a selection of the above-mentioned presentations willbe published in a proceedings volume (Springer LNAI) early in 2007.

Keywords. Affordances, cognitive systems, biologically inspired systems, models of biological systems, attention models, interpersonal maps, human wayfinding, motivations, robot control architectures, hybrid robot control, goal-directed robot control, reactive robot control, ubiquitous robotics, cooperative robotics, robot learning, reinforcement learning, concept learning, action-oriented perception, function-based perception, spatial perception and cognition, object recognition, function-based reasoning, formalization, action awareness, similarity measurements, geospatial ontologies, spatial representations, agent, simulation, graphical models, ambient intelligence

06231 Executive Summary – Towards Affordance-Based Robot Control

This article summarizes the objectives and the program of the Dagstuhl seminar 06231, "Towards Affordance-based Robot Control". It was held from June 5 to June 9, 2006, at the International Conference and Research Center for Computer Science Schloss Dagstuhl near Wadern, Germany.

Dagstuhl Seminar Proceedings 06231
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http://drops.dagstuhl.de/opus/volltexte/2006/722

Keywords: Affordances, robot control, robot learning, action-oriented perception, robot perception, biologically inspired systems, cognitive systems

Joint work of: Rome, Erich; Hertzberg, Joachim; Dorffner, Georg; Doherty, Patrick

Full Paper: http://drops.dagstuhl.de/opus/volltexte/2006/725

Action Awareness – Enabling Autonomous Robots to Optimize, Transform, and Coordinate Plans

Michael Beetz (TU München, D)

As autonomous robots are to solve more and more complex tasks in increasingly challenging domains, their control systems are becoming more complex too — often compromising their adaptivity and robustness. A promising approach to solve this problem is to provide the robots with reflective capabilities. Robots that can reflect on the effects and expected performance of their actions, are more aware and knowledgeable of their capabilities and shortcomings.

In this talk, we introduce a computational model for what we call action awareness. To achieve this awareness, robots learn predictive action models from observed experience. This knowledge is then used to optimize, transform and coordinate plans. We apply this computational model to a number of typical robotic scenarios where action awareness can substantially improve the robots' performance.

Cognitive Modeling of Motivations for Artificial Agents

Gordon Bernedo-Schneider (Universität Kassel, D)

People suffering from Utilization Behavior seem not to be able to resist the stimulative nature of objects. Their compulsion to use objects makes it impossible for them, to follow their own goals and intentions. Healthy people, however, have mechanisms to restrict the number of Affordances. This limitation is due to the agents motives. An observer is in need of a certain function, because of his present motivational or emotional state. To get a better understanding, we should avoid regarding Affordances in isolation, but try to integrate them into a whole cognitive architecture. Since the PSI-Theory of Dietrich Dörner provides a comprehensive cognitive architecture – including motives – this theory is presented.

Keywords: Affordance, Motivation, Utilization Behavior

Computational Attention Systems and their Applications

Simone Frintrop (KTH Stockholm, S)

This talk gives an overview on computational visual attention systems and their applications. The concept of visual attention was of much interest in the computer vision and robotics community during the last years, since it enables to restrict processing to interesting parts of the images. The talk starts by introducing the term of attention, especially visual attention, and mentiones the psychological and neurobiological background of the concept.

Then, I explain the structure of standard systems for visual attention and give an overview over the history of attention systems and the currently most important systems in the field. The talk concludes with a review of applications of attention systems in computer vision and robotics.

Keywords: Computational visual attention, regions of interest, computer vision, robotics, applications

Interpersonal Maps through Interaction Behaviour

Verena V. Hafner (TU Berlin, D)

In order to investigate the possibility of a common representation space for comparing one's own behaviour and the behaviour of others, this paper introduces the notion of "interpersonal maps", a geometrical representation of the relationships between a set of proprioceptive and heteroceptive information sources. Such maps can be used to detect specific types of interactions between agents, like imitation. Moreover, in cases of strong couplings between agents, such representations permit to directly map an agent's body structure onto the structure of an observed body, thus addressing the body correspondence problem. These various cases are studied with several robotic experiments using four-legged robots either acting independently or being engaged in delayed imitation. Through a precise study of the effects of the imitation delay on the structure of the interpersonal maps, the paper shows the potential of this "we-centric" space to account for both imitative and non-imitative interactions.

Keywords: Interaction, behaviour, interpersonal maps, robot experiments

Joint work of: Hafner, Verena V.; Kaplan, Frederic

Learning of interaction possibilities

Jörg Irran (ÖFAI - Wien, A)

A learning approach is proposed that enables an artificial agent to gain meaning in its own terms about the action possibilities offered by its environment as well as the consequences of acting within its environment based on its own perception of the world.

Therefore the concept of affordances as introduced by Gibson (1986) is utilised.

Using the described learning approach an agent equipped with a limited set of reflex like actions develops through experiencing these consequences and through gaining knowledge about the involved environmental entities.

Keywords: Affordance Cognitive Robot Learning Interaction

Joint work of: Irran, Jörg; Kintzler, Florian; Dorffner, Georg

The Role of Affordances in (Semantic) Similarity Measurements

Krzysztof Janowicz (Universität Münster, D)

Semantic similarity measurement plays a significant role in semantic interoperability and in information retrieval within the geo domain, as it supports the detection of conceptually close but not identical entities. In feature-based models similarity measurement is done by comparing common and different features such as parts, attributes and functions. After giving a brief introduction into similarity theories in general and shortcomings of feature-based models in particular, a role based extension grounded in the notion of affordances and Sowas theory of thematic roles will be discussed. The integration of this extension into an existing feature-based model (MDSM) and the resulting improvements will be demonstrated by measurement examples.

Cognitive Modeling of Spatial Reference in Human-Robot Interaction

Reinhard Moratz (Universität Bremen, D)

The visionary goal of an easy to use service robot implies intuitive styles of interaction between humans and robots. Such natural interaction can only be achieved if means are found to bridge the gap between the forms of object perception and spatial reference systems maintained by such robots, and the forms of language, used by humans, to communicate such knowledge.

We developed a system that uses an affordance-based object recognition module and a computational model of human spatial reference strategies to bridge this gap.

Keywords: Human-Robot Interaction, Spatial Reference Systems

Perceiving Drivable Surfaces in Outdoor 6D SLAM

Andreas Nüchter (Universität Osnabrück, D)

A basic issue of mobile robotics is generating environment maps automatically. Outdoor terrain is challenging since the ground is uneven and the surrounding is structured irregularly.

In earlier work, we have introduced 6D SLAM (Simultaneous Localization and Mapping) as a method to taking all six DOF of robot poses (x, y, z translation; roll, pitch, yaw angles) into account. This paper adds to 6D SLAM a method for extracting drivable surfaces in the 3D maps while they are being generated. Experiments have been made in a Botanical Garden, with drivable surfaces consisting of gravel paths or lawn, both involving significant slope.

Joint work of: Nüchter, Andreas; Hertzberg, Joachim; Lingemann, Kai

Full Paper:
http://kos.informatik.uni-osnabrueck.de/download/robotik2006.pdf

See also: Andreas Nüchter, Kai Lingemann, and Joachim Hertzberg. Extracting Drivable Surfaces in Outdoor 6D SLAM, in Proceedings of the 37nd International Symposium on Robotics (ISR '06) and Robotik 2006, Munich, Germany, 2006

Affordance based Modeling of Perception in the Context of Reinforcement Learning

Lucas Paletta (Joanneum Research - Graz, A)

Human cognition embodies visual stimuli and motor interactions in common neural circuitry. Affordances (Gibson 1979) have been presented as a conceptual model of cued prediction for opportunities of agent-environment interaction. Research for technical systems so far focused on determining simple feature-function relations heuristically, or highlighted the relevance of mapping from visual to haptic perceptual categories. In contrast, we are focusing to investigate the relevance of learning of affordance cues. In this context, reinforcement learning provides the methodology to determine a specific perceptual state that owns both the predictive characteristics and the representation of an affordance based visual cue. The learning process is applied to bridging two basic components characterizing the interaction component: (i) affordance hypothesis verification, by recognizing relevant events in interaction via perceptual entities that specify the outcome of an affordance related behavior, and, the predictive aspect, i.e., (ii) affordance cueing: predicting interactions via perceptual entities. We illustrate in experimental results of a robotic system scenario how the outcome of an affordance related behavior provides the reinforcement signal that can be propagated back towards early affordance cueing. Upon convergence of the learning algorithm, we were able to identify an early perceptual state that enables to discriminate in a stochastically optimal way the capability to predict a future interaction opportunity with high confidence.

Keywords: Affordance cueing, function based object recognition, reinforcement learning

Joint work of: Paletta, Lucas; Fritz, Gerald

Agent-based Simulation of Human Wayfinding: A Perceptual Model for Unfamiliar Buildings

Martin Raubal (Universität Münster, D)

Researchers in the areas of human wayfinding, spatial cognition, computer science, and artificial intelligence have developed cognitively based computational models for wayfinding. These models focus primarily on learning a spatial environment and on the exploration of mental representations rather than the information needs for wayfinding. It is important to consider the information needs because people trying to find their ways in unfamiliar environments do not have a previously acquired mental representation but depend on external information. The fundamental tenet of this work is that all such information must be presented to the wayfinder at each decision point as knowledge in the world.

Simulating peoples wayfinding behavior in a cognitively plausible way requires the integration of structures for information perception and cognition in the underlying model. We use a cognizing agent to simulate peoples wayfinding processes in an unfamiliar building. The agent-based model is grounded in the ontology and epistemology of the agent and its environment. Both are derived from human subjects testing using an ecological approach. This leads to two tiers in the conceptual model: simulated states of the environment and simulated beliefs of the agent. The agent is modeled with state, an observation schema, wayfinding strategies, and commonsense knowledge. The wayfinding environment is modeled as a graph, where nodes represent decision points and edges represent lines of movement.

The perceptual wayfinding model integrates the agent and its environment within a Sense-Plan-Act framework. It focuses on knowledge in the world to explain actions of the agent while performing a wayfinding task. We use the concepts of affordance and information to describe what kinds of knowledge the agent derives from the world by means of visual perception. Affordances are possibilities for action with reference to the agent. Information such as from signs is necessary for the agent to decide which affordances to utilize. During the navigation process the agent accumulates beliefs about the environment by observing task-relevant affordances and information at decision points. The utilization of a so-called go-to affordance, i.e., following a pathway, leads the agent from one node to another where it is again provided with percepts. A successful navigation corresponds to the agents traversal from a start to a goal node. The perceptual wayfinding model concentrates on the actual information needs during wayfinding and does not focus on learning a spatial environment.

The proposed formal algebraic specifications of the agent-based model within a functional programming environment can be used to simulate peoples wayfinding behavior in spatial information and design systems in a cognitively plausible way. The simulation helps to determine where and why people face wayfinding difficulties and what needs to be done to avoid them. We employ the specific case

of wayfinding in an airport to demonstrate the perceptual wayfinding model. The result can be practically used to test the signage in the airport.

Keywords: Human Wayfinding, Agent, Information, Affordances, Spatial Perception and Cognition, Algebraic Specifications, Simulation

Cognitive Systems, Affordances and the MACS Project

Erich Rome (Fraunhofer IAIS - Sankt Augustin, D)

The goal of the MACS project is to investigate a concept from psychology, J. J. Gibsons affordances, and its utilization for Robotics. According to Gibson, an affordance is a resource or support that the environment offers a being for action, and the being must in turn possess the capability to perceive and act upon it. A new hybrid control architecture shall provide support for perceiving, learning and using affordances, not only reactively, but also in a goal-directed way. Explicit usage of and reasoning about affordances requires possibilities for representations of affordances and thus a formalization of the notion of affordances. This is a diversion of the classical ecological approach. The chosen formalization is an extension of the TAL temporal action logic and characterizes affordances by the use of events.

For the perception of affordances, we extend Gibsons approach under acknowledgment of Neissers understanding that visual feature representation on various hierarchies of abstraction is mandatory to appropriately respond to environmental stimuli. We developed a refined concept on affordance perception by proposing (i) an interaction component (affordance recognition: recognizing relevant events in interaction via perceptual entities) and (ii) a predictive aspect (affordance cueing: predicting interaction via perceptual entities). This innovative conceptual step enables firstly to investigate the functional components of perception that make up affordance-based prediction, and secondly to lay a basis to identify the interrelation between predictive features and predicted event via machine learning technology.

In an initial learning phase, the mobile robot will acquire knowledge about relations between perceptual entities, robot actions and their outcome. These relations determine the possibilities of the robots interaction with its environment. Generalizations of the increasingly complex interactions will be generated, finally enabling the robot to use affordances purposefully and to act meaningfully in novel situations, too.

Keywords: Affordances, mobile robot control, robot perception, robot learning

Joint work of: Rome, Erich; Paletta, Lucas; Doherty, Patrick; Sahin, Erol; Dorffner, Georg; et al.

PEIS Ecology: Ambient Intelligence meets Autonomous Robotics

Alessandro Saffiotti (University of Örebro, S)

A common vision in the field of autonomous robotics is to create a skilled robot companion that is able to live in our homes and perform physical tasks to help us in our everyday life. Another vision, coming from the field of ambient intelligence, is to create a network of intelligent home devices that provide us with information, communication, and entertainment. We propose to combine these two visions into the new concept of an ecology of networked Physically Embedded Intelligent Systems (PEIS). In this talk, I will introduce this concept, and illustrate it by describing an experimental system that involves real robotic devices.

Keywords: Autonomous robotics, ambient intelligence, ubiquitous robotics, cooperative robotics

Full Paper:
http://aass.oru.se/∼asaffio/Papers/icra06b.html

To Afford or not to Afford: Formalizing Affordances for Robot Control

Erol Şahin (Middle East Technical University - Ankara, TR)

The concept of affordance was proposed by J.J. Gibson in 1980's as a means to understand how object's inherent meanings can be perceived and how they would affect behaviors. It refers to the action possibilities that the environment offers to the organism. It has been one of the most elusive concepts that influenced studies ranging from human-computer interaction to neuroscience. However, despite the existence of a large body of literature on the concept, when one starts reviewing the literature, one would often find himself faced with different facades of this term, sometimes contradictory, more like the description of an elephant by the six blind man in the famous Indian tale.

We, as roboticists, are interested in how the concept of affordances can change our view to the control of an autonomous robot and how it can be embedded into a robot control architecture. In our presentation, we first, summarize the concept of affordance, as proposed by Gibson, and reviewed a wide range of affordance-related studies in different fields. Then, we review four different formalizations of affordances as proposed by Turvey(1992), Stoffregen(2003), Chemero(2003) and Steedman(2002) in a common framework. We conclude that, none of these existing formalizations, provided a clear and complete understanding of the concept, and are insufficient to form a basis for using affordances in robot control. In our quest to create a formalism to our purpose, we first point out that there are

three different perspectives to view affordances; namely agent (interacting with the environment), observer (observing the interaction between the agent and the environment) and entity (part of the environment that is being interacted) perspectives. Then we propose a new formalization which defined an affordance as an acquired relationship between the environment and the robot (organism) based on the interaction between them and the effect of the interaction. We discus how affordances can be acquired as such relations, the nature of these relationships and the advantages of using affordances in robot control.

Finally, we hint the implications of proposed formalization of affordances on planning in robot control.

Keywords: Affordance, robot, control architecture, formalization

Joint work of: Şahin, Erol; Çakmak, Maya; Doğar, Mehmet R.; Uğur, Emre; Üçoluk, Göktürk

Use of Affordances in Geospatial Ontologies

Sumit Sen (Universität Münster, D)

Affordances are important constituents of our knowledge about geospatial artifacts. They should be seen as complimentary to the knowledge of functions of various agents in respect to the geospatial artifacts. While functions combine to form complex activities in which agents can participate, affordances can be nested, or sequential in nature. We extract nested and sequential affordances based on statistical analysis of formal texts to construct hierarchies. Our approach considers affordances of classes of artifacts and thus is relevant to specifications of ontologies. The use of such affordances in function based ontologies is demonstrated using a Road ontology example.

Keywords: Geospatial artifacts, functions, affordances, ontologies

Function-Based Object Recognition

Louise Stark (Univ. of the Pacific - Stockton, USA)

Function-based object recognition provides the framework to represent and reason about object functionality as a means to recognize novel objects and produce plans for interaction with the world. When function can be perceived visually, function-based computer vision is consistent with Gibson's theory of affordances. Objects are recognized for their functional attributes. The Gruff object recognition system reasons about and generates plans for understanding 3-D scenes of objects. One extension to the Gruff system incorporates contextual cues which can be used to identify evidence of potential functionality. The methodology of context-based reasoning relies on determining the significance of the accumulated functional evidence derived from the scene.

Keywords: Function-based recognition, object recognition, affordances, form and function

Function-based Reasoning for Goal-Oriented Image Segmentation

Melanie Sutton (University of West Florida - Pensacola, USA)

Research in computer vision is aimed at making meaningful decisions about scenes of the physical world, based on analyzing images. Segmentation strategies for understanding scenes are one critical step in this process. Scene segmentation is simply the process of attaching symbolic labels to the significant areas in the image of the scene. The particular avenue explored here is based on a novel approach of autonomously directing image acquisition and range segmentation by determining the extent to which surfaces in the scene meet specified functional requirements for generic categories of objects. Results are provided for real data derived from a stereo camera system, the Small Vision System stereo processing software, and the Generic Recognition Using Form and Function object recognition system. An approach for the analysis of the results is outlined to determine the "optimal" range imaging parameters that lead to the most metrically accurate derived scene segmentations and recovered models, compared to known ground truth. In addition, a task-driven assessment of the overall system is outlined to determine the success of the object recognition system's ability to autonomously and dynamically alter image acquisition and range segmentation parameters according to provided tasks and detected environmental conditions present during data collection.

Keywords: Segmentation, object recognition, function-based reasoning

Interactive Learning of concepts and spatial representations

Elin-Anna Topp (KTH Stockholm, S)

When a service robot is supposed to provide its services in a domestic or office environment, it consequently has to work in the proximity of humans and interact with them. Providing services will in most cases require mobility, which means that the robot has to move in populated areas. This work environment has to be assumed initially unknown and might be subject to changes. The human user of a particular robot though knows the environment very well and might want the robot to report its own whereabouts in personally preferred terms. In other words, the robot needs the ability to refer to the spatial concepts and semantics the user has in mind. A shared representation is needed.

The general concept for Human Augmented Mapping is designed to link a hierarchy of space representations with interaction modalities. Within this hierarchy different aspects of the respective representations are subject to the work which is conducted as part of the European Integrated Project "Cogniron - The Cognitive Robot Companion". Believing that a metric (feature based)

SLAM generated map still provides best information for exact navigation, such an approach is integrated into the hierarchy as a basic block. In order to reduce complexity and to establish the link to a conceptual environment model for communication with human users a topological layer is build on top of this, using a momentum and geometric feature based descriptor to delimit regions in the environment. Those regions form the nodes of a topological graph.

The conceptual level allows to communicate in a comprehensible way with humans by providing an in itself hierarchical environment model to incorporate the information given by the user interactively.

Ambiguities have to be detected based on localisation and classification of places visited before and resolved in cooperation with the user.

Both the concept, the environment model and the space delimiting approach will be presented to give an overview of the idea of interactive mapping.

Using robots to model biological perception systems

Barbara Webb (University of Edinburgh, GB)

The term 'model' has many uses, for example, animals can be considered as analogical models that inspire ideas for how to build robot perception systems. However in this talk I will describe robots that are physically implemented models of sensorimotor control in insects. These allow us to test our understanding of the mechanisms of biological perception, in a way that closes the perception action loop, and can be validated in 'ecological' situations. In many cases, the mechanism can be described as a matched filter, that is, the sensor design and processing directly transforms the input into the task relevant output. This could be considered a low level implementation of affordances. I will describe several specific examples, and then go on to the question of how higher level capabilities, such as smoothly combining several behaviours, can be acheived. Even in insect systems, the evidence points towards a need for (simple) internal models for predicting the sensory outcome of the animal's own actions.

Learning about actions, goals and objects

Jeremy L. Wyatt (University of Birmingham, GB)

Robot learning is sometimes extremely successful, but largely on constrained problems. I will discuss ways of relaxing common assumptions about the form of the models used to learn about actions and objects. The talk will review work on learning action prototypes for a robot via unsupervised clustering of experience. I will then show how we can combine unsupervised clustering with supervised learning in a graphical model of goal directed (or intentional) actions.

The system presented is able to learn complex action models for intentional actions like reaching for, pushing, rotating and grasping objects. It learns these

by watching video streams of humans performing these actions. Finally I will offer some thoughts about how objects need to be represented in order to facilitate learning of different types of predictive (or forward) models of motor effects.

Keywords: Robot learning, graphical models, actions