Abstracts of Recent PhDs

Qualified Predictions for Large Data Sets
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Abstract

The Inductive Confidence Machine (ICM) provides an alternative method to that of the Transductive Confidence Machine (TCM) for complementing the bare predictions produced by traditional machine-learning algorithms with measures of confidence. These measures give an indication of how 'good' each prediction is, which is highly desirable in risk-sensitive applications. The motivation behind the introduction of the ICM was to produce algorithms that overcome the computational inefficiency problems suffered by TCMs.

In this thesis, we study the ICM method, describing how it works and how it can be applied to different traditional machine-learning algorithms. More specifically we detail how we implemented the Nearest Neighbours and Neural Networks ICMs for pattern recognition, and the Ridge Regression and Nearest Neighbours Regression ICMs. The results obtained by our methods demonstrate that the accuracy of ICMs in terms of error percentage is comparable to both traditional methods and TCMs and that the confidence measures they produce are useful in practice. In addition, our time efficiency comparisons exhibit their huge advantage in this sector over TCMs. These properties make ICMs the most suitable choice for obtaining qualified predictions when dealing with large data sets.

Monitoring Large-Scale Multi-Agent Systems using Overhearing
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Abstract

Overhearing is fast gaining attention as a generic method for monitoring open, distributed multi-agent systems. In such settings, agents’ internal structure is not generally known to a monitoring agent, but overhearing does not require such knowledge. Instead, the monitoring agent uses the overheard routine communications as a basis for inference about the other agents.

Previous work on overhearing investigated an extensive set of techniques and implementations of overhearing. However, focusing mainly on its potential applications, those investigations often rely on assumptions related to the fundamentals of overhearing. In contrast, we dedicate our research to a comprehensive study of the fundamental building blocks that allow overhearing in the first place tackling those problematic assumptions. In particular, our study focuses on overhearing in large-scale multi-agent systems and addresses the specific challenges and limitations that characterize such settings.

The first overhearing building block, addressed by our research, is the representation of multi-agent conversations. Here, building on the insights gained from analyzing the strengths and weaknesses of the rather radical Petri net approaches introduced by previous work, we propose a novel representation technique especially suitable for overhearing. Furthermore, we show this representation to be more scalable than previous representations, and thus more appropriate for monitoring conversations in large-scale settings.

Next, we addressed the building block of conversation recognition—the process of identifying the actual conversation based on a sequence of overheard messages. Although conversation recognition is a key step in overhearing prior to any possible inference, it is often discarded by previous investigations. Our work addresses the challenges related to conversation recognition by first introducing a formal model of overhearing. Then, based on this model, we provide a skeleton algorithm for conversation recognition, and provide instantiations of it for lossless and lossy settings. Since in large-scale settings overhearing agent has to process large quantities of intercepted messages, we also analyze the efficiency of those algorithms in terms of their run-time complexity.

The final building block addressed is selective overhearing, that is, overhearing under the restriction of...
selectivity. The restriction of selectivity is mainly
compelled by the specific characteristics of large-scale
multi-agent systems. In such settings, it is reasonable to
assume that the overhearing resource will be essentially
limited, thus allowing the overhearing agent for overhear
only a subset of inter-agent communications. Most
previous investigations on overhearing ignore the
limitation of selectivity, assuming that all relevant inter-
agent communications can be overheard. In contrast, our
work provides an empirical study of selective overhearing
committed by both centralized and distributed teams of
collaborative overhearing agents.

Cognitively Inspired Decision Making for Software Agents: Integrated Mechanisms for Action
Selection, Expectation, Automatization and Non-Routine Problem Solving

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Abstract

Despite impressive advances in the past decades,
autonomous agents living in dynamic and unpredictable
environments are typically equipped with simple decision-
making mechanisms in their sense-decide-act routines.
These agents deal mostly with one goal at a time. This
research aspires to model, design and/or implement a
sophisticated decision-making mechanism that selects the
agent’s next action with different levels of awareness:
automatized skills, consciously mediated routine solutions
and consciously deliberated non-routine solutions. Such a
decision-making mechanism is presented in a ‘conscious’
software agent framework called IDA that implements
Baars’ Global Workspace Theory of consciousness. IDA
integrates many computational and conceptual
mechanisms, among which this research deals with its action
selection, expectation, automatization and non-routine
problem-solving modules.

The overarching continual task of an agent’s intelligence is
for the service of choosing, at each moment in time, the
appropriate action in response to exogenous and endogenous
stimuli. IDA’s action selection mechanism (ASM) can
interleave and prioritize actions of different and competing
goal hierarchies. The ASM system is implemented as a
domain-independent and reusable framework for behavior
networks and is tested as a controller to a khepera robot
operating in a real-world domain.

We humans have the amazing ability to learn a procedural
task (e.g., walking) so well that we do not need to think about
the task consciously in order to accomplish it. This ability is
what we call automatization. Once a task has been
automatized, there is no need for attention to be paid to its
execution unless the expected result does not occur. At
failure of expectation, deautomatization process temporarily
disables the automatization effects and ‘conscious’ control
plays a role to deal with the failure situation. We
implement the automatization and deautomatization cognitive functions
as a self-organizing system in the IDA framework.

Non-routine problem solving is the ability to devise
unexpected, and often clever, solutions to problems that have
never been encountered before. We will present a detailed
design and specification of a non-routine problem-solving
mechanism as a special goal context hierarchy that guides a
deliberative solution search process, which we will discuss in
IDA’s cognitive cycle.

Autonomy vs. Conformity: An Institutional Perspective on Norms and Protocols

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Abstract

The research presented in this thesis is part of the ToKeN
project ANITA (Administrative Normative Information
Transaction Agents). In this domain, the main challenges
concern both the shortage of information (not being able
to find legally relevant data that should be available) as
well as the abundance of information (e.g., violating
privacy rights). Although the agents decide autonomously
whether to share information based on (local) norms, a
global frame was needed for the enforcement of (global)
norms given by laws and regulations of the domain. In
most software and agent methodologies, such regulations are
seen only as extra requirements in the analysis phase,
and are thus hard-coded into the software or agents
themselves. If, however the regulations change, all design
steps have to be checked and all code verified to ensure
compliance to the new regulations. The alternative is to
have an explicit representation of the norms, for example,
by the introduction of an electronic institution, but this
approach requires some form of enforcement to ensure the
compliance instead. The introduction of an electronic
institute in highly regulated domains such as the ANITA
scenario requires us to solve issues related to the
abstractness of human regulations, the lack of operational
information and the implementation of norm enforcement
from an institutional perspective. In this thesis, we solve
these problems by the introduction of a framework for
making the connections between the norms and the
practice explicit. To ensure that none of the norms derived
from law are violated, an enforcement mechanism is
presented based on monitoring and punishing rather than