

CLASSiC

D1.4.1: Improved POMDP-based dialogue system

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CLASSiC

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Copies of reports and other material can also be accessed via the project's administration homepage,
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Executive summary

This document is a short report to accompany the Prototype deliverable 1.4.1, due at month 12 of the CLASSiC project. It describes the improved version of the Hidden Information State (HIS) POMDP based spoken dialogue system. A brief overview is given of the system's functionality, the components it consists of and how the software is organised. 3 project publications [1, 2, 3] relate directly to this deliverable, and their abstracts are presented in the Appendix. They are available at www.classic-project.org

1 Introduction

This document describes the prototype deliverable consisting of improved version of the Hidden Information State (HIS) POMDP based spoken dialogue system. The task domain for this system is TownInfo, i.e., users can talk to the system and try to find a hotel, bar, or restaurant in a town. They can express their preferences as to their location, type of food, price range, and so on. They can also change their mind or adjust their constraints if no venues match them, and they can ask for specific information about venues, such as address or telephone number.

The system consists of several modules, ranging from speech understanding and generation components to the central component, the dialogue manager. In order to deal with the uncertainties due to speech recognition and understanding errors, the dialogue manager uses a Partially Observable Markov Decision Process (POMDP) approach. In this approach, the dialogue state (containing in particular the user's goal) is considered unobservable, and instead of considering the most probable state, a probability distribution over dialogue state hypotheses (the belief state) is maintained. The dialogue acts the dialogue manager selects to form the system responses are based on these belief states.

In the following sections, a brief overview will be given of the different components in the current prototype, as well as the HIS graphical interface. For a more detailed description of the HIS system, see [1].

2 Speech understanding

The speech understanding part of the system consists of the HTK/ATK speech recogniser, producing a list of word sequence hypotheses from the user's speech input, and the recently developed statistical semantic decoder (see deliverable D2.1), producing a list of dialogue act hypotheses based on the speech recognition result.

For each word sequence in the N-best list of ASR hypotheses the semantic decoder produces a list of dialogue act hypotheses, after which equivalent dialogue acts are merged, resulting in a single N-best list of dialogue act hypotheses. These dialogue acts are used by the dialogue manager to update the dialogue belief state and select an appropriate response dialogue act. The decoder uses a system of trained SVM classifiers to predict substructures of the user act hypothesis [4].

3 Speech generation

From the system dialogue acts, selected by the dialogue manager as appropriate responses, a natural language utterance is produced in a template based fashion. The HMM-based speech synthesiser [5] then produces the speech signal for the system utterance. Two different voices have been trained for use in the TownInfo application.

4 Dialogue management

In order to deal with the intractability of both updating belief states and action selection/policy optimisation, the Hidden Information State dialogue manager employs two techniques of compressing the dialogue state space. During the dialogue, the space of user goals is partitioned into classes of equally probable

user goals in each turn. After updating the belief state, it is mapped into a much smaller summary space, in which action selection takes place, resulting in a summary action that gets mapped back into master space using information from the original belief state.

Since the start of the project, the system has been improved in several ways:

1. improved policy optimisation: parallelisation of training process and the incorporation of increasing levels of noise in training [2];
2. refined summary space mapping and action selection heuristics;
3. redesign of the user act model, using the notion of dialogue act preconditions [3].

5 Graphical interface

The graphical user interface (see Figure 1 for a screen shot) is merely used for research purposes and is not intended to be shown to end users. The interface shows the N-best output from ASR (top left) and semantic decoding (bottom left), the dialogue belief state (centre), and the output system act (bottom right) and corresponding system utterance (top right).

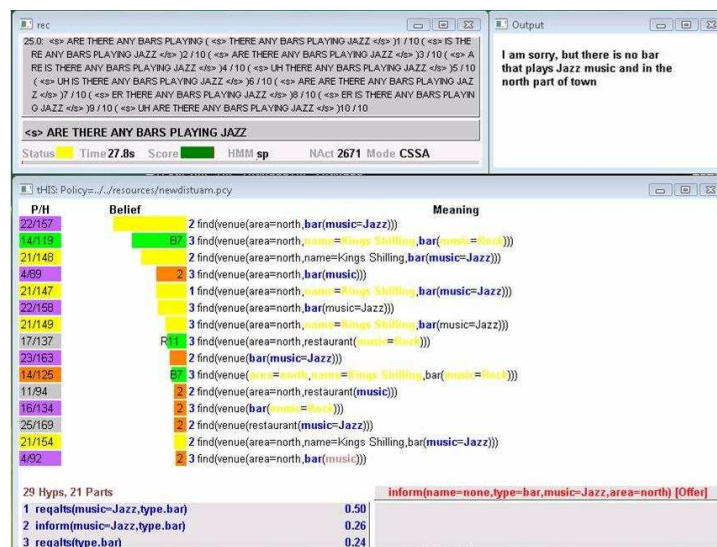


Figure 1: Screen shot of the HIS graphical user interface.

The dialogue belief state consists of a list of dialogue state hypotheses with their probabilities (indicated by the size of the bars in the middle column labelled 'Belief'). On the right of each hypothesis, in the column labelled 'Meaning', expressions of the user goal for that hypothesis are given, for example `find(venue(area=North),bar(music=Jazz))`.

6 Software

The software for the HIS prototype deliverable is organised in several directories; a readme file in the root directory contains instructions for running the dialogue system as well as the test harness for training and evaluating dialogue management policies.

- **atk**: speech recognition and synthesis software, including:
 - **HTKLib**: C sources of the HMM toolkit;
 - **ATKLib**: C++ sources of the application toolkit for HTK;
 - **SYNLib**: C sources of the HMM based (HTS) and FLite synthesisers;
- **SemIO**: C++ sources of SVM based semantic decoder software;
- **tHIS**: C++ sources of dialogue management software, including:
 - **HISLib**: the HIS dialogue manager;
 - **UMLib**: user simulation and evaluation;
 - **TDMan**: the test harness;
- **resources**: acoustic and language models, 3 different voices, trained dialogue management policies, the domain ontology and database, configuration files, and other resources;
- **demoSys**: C++ sources of the main program for running the dialogue system.

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The above papers are available for download on the CLASSiC website: www.classic-project.org

Appendix: abstracts of publications associated with this deliverable

The Hidden Information State model: a practical framework for POMDP based spoken dialogue management

S. Young, M. Gašić, S. Keizer, F. Mairesse, B. Thomson, and K. Yu

In *Computer Speech and Language*, 2009. (Accepted pending minor revisions)

Abstract:

This paper explains how Partially Observable Markov Decision Processes (POMDPs) can provide a principled mathematical framework for modelling the inherent uncertainty in spoken dialogue systems. It briefly summarises the basic mathematics and explains why exact optimisation is intractable. It then describes in some detail a form of approximation called the *Hidden Information State model* which does scale and which can be used to build practical systems. A prototype HIS system for the tourist information domain is evaluated and compared with a baseline MDP system using both user simulations and a live user trial. The results give strong support to the central contention that the POMDP-based framework is both a tractable and powerful approach to building more robust spoken dialogue systems.

Training and evaluation of the HIS-POMDP dialogue system in noise

M. Gašić, S. Keizer, F. Mairesse, J. Schatzmann, B. Thomson, K. Yu, and S. Young

In Proceedings of the 9th SIGdial Workshop on Discourse and Dialogue, Columbus, Ohio, June 2008

Abstract:

This paper investigates the claim that a dialogue manager modelled as a partially observed Markov decision process (POMDP) can achieve improved robustness to noise compared to conventional state-based dialogue managers. Using the Hidden Information State (HIS) POMDP dialogue manager as an exemplar, and an MDP-based dialogue manager as a baseline, evaluation results are presented for both simulated and real dialogues in a Tourist Information Domain. The results on the simulated data show that the inherent ability to model uncertainty, allows the POMDP model to exploit alternative hypotheses from the speech understanding system. The results obtained from a user trial, show that the HIS system with a trained policy performed significantly better than the MDP baseline.

Modelling user behaviour in the HIS-POMDP dialogue manager.

S. Keizer, M. Gašić, F. Mairesse, B. Thomson, K. Yu, and S. Young

In Proceedings of the IEEE Workshop on Spoken Language Technology (SLT), Goa, India, December 2008

Abstract:

In the design of spoken dialogue systems that are robust to speech recognition and interpretation errors, modelling uncertainty is crucial. Recently, Partially Observable Markov Decision Processes (POMDPs) have shown to provide a well-founded probabilistic framework for developing such systems. This paper reports on the design and evaluation of the user act model (UAM) as part of the Hidden Information State (HIS) POMDP dialogue manager. Within this system, the UAM represents the probability of a user producing a certain dialogue act, given the last system act and the dialogue state. Its design is domain-independent and founded on the notions of adjacency pairs and dialogue act preconditions. Experimental evaluation results on both simulated and real data show that the UAM plays a significant role in improving robustness, but it requires that the N-best lists of user act hypotheses and their confidence scores are of good quality.