Multi-Modal Generative Models for Learning Epistemic Active Sensing
Timo Korthals ¹, Daniel Rudolph, Jürgen Leitner², Marc Hesse ³, and Ulrich Rückert ¹

¹ Bielefeld University, Cognitronics & Sensor Systems, Bielefeld, Germany
² Queensland University of Technology, Australian Centre for Robotic Vision, Brisbane, Australia

Approach
We present a novel approach of multi-modal deep generative models and apply this to coordinated heterogeneous multi-agent active sensing [2]. A major approach to achieve this objective is to train a multi-modal variational Auto Encoder (M²VAE) [1] that integrates all the information different sensor modalities into a joint latent representation. Furthermore, we derive an objective from the M²VAE that enables the maximization of the evidence lower bound via selection of sensor modalities. Using this approach as a direct reward signal to a multi-modal and multi-agent deep reinforcement learning setup leads intuitively to an epistemic active sensing behavior [3] that coordinates the ambiguity of observations.

Multi-Modal Generative Models (M²VAE)
- Objective is derived from the full marginal joint log likelihood [1]
- M²VAE respects all permutations
- All modal. are trained jointly
- VAE objective
- Joint VAE objective
- MVAE objective
- Proposed M²VAE objective
- 2 modalities: \(|M|=2\)
- \(|M|\) modalities: \(|M|\) only

Learning Epistemic Active Sensing
Training of M²VAE
- All permutations of modalities \((a,b,c)\) are trained on the environment observations
- ELBO becomes higher for greater information content in the observation
- KL behaves proportional to the ELBO, as the M²VAE prevents confusion in the latent space

Training Epistemic Sensing
- All perceptions in the environment are embedded by the M²VAE for every object, to build a perceived env.
- New observations are fused with prior observations via de/encoding
- As the M²VAE derives the state and reward information, the env. becomes a perceived environment

State & Reward Construction
- Observation S is constructed as \((Z,D)\) for every robot \(i\)
- Reward results from M²VAE’s KL

Conclusion
- M²VAE enables inference, sensor fusion, and epistemic behavior through ambiguity-resolving actions in a deep reinforcement application
- M²VAE is trained unsupervised based on sensory outputs to build a coherent and expressive posterior distribution between all subsets of modalities
- Max. of the M²VAE’s ELBO via actions leads inherently to the principle of active sensing and min. of free energy [3]

Contact
Bielefeld University Center of Excellence Cognitive Interaction Technology Cognitronics & Sensor Systems Inspiration 1, 33619 Bielefeld - Germany

Contact Persons
Timo Korthals
Room: 3.413
Tel: +49 521 106 67367
tkorthals@cit-ec.uni-bielefeld.de

Submission Video
http://www.ks.cit-ec.uni-bielefeld.de