Latent Goal Analysis: Learning goals and body schema from generic rewards

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I. INTRODUCTION

Goals are abstractions of high-dimensional world states that express intelligent agents' intentions underlying their actions. Goals are considered to organize the behavior of both humans and robots. For instance in robot *planning* as well as motor *control* goals describe the desired outcome of future actions. Goals are a fundamental concept also in neuroscience and psychology, e.g. in formulations of *internal models* [1], motivation psychology [2], or teleological action understanding [3].

We recently argued [4] that the *achievement semantics* of goals point out an immediate need for an *evaluation* of the own action's effect (see Fig. 1). In hand-eye coordination this evaluation, or rather its learning, is often referred to as *self-detection* [5] or *body schema* [6]: the hand needs to be localized e.g. from vision data. Goals are only useful when this "ground-truth" position is available. Indeed, there very relation allows for versatile motor control as well as self-supervised motor learning. Due to the vital relation between both, we argue to learn them within a joint framework. Yet, how could an agent learn such goal systems in which goals, body-schema, and their relation are identified?
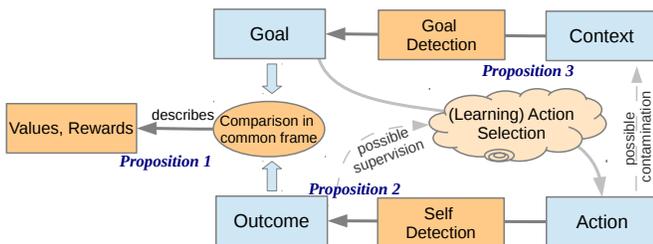

Fig. 1. Proposed conceptualization of "goals" in relation to self-detection (body schema) and rewards [4].

II. LATENT GOAL ANALYSIS

Our main interest is the fully autonomous learning of goal systems, which disqualifies learning from an external supervised learning signal. Also unsupervised learning does not seem appropriate. While several approaches have shown the learning of body-schemas from just signal statistics, purely descriptive statistics can not account for the desire or intention that is inherent to the achievement of goals. Therefore we suggest to learn both goals and self-detection from a reward learning signal, which could be generated by intrinsic motivation measures.

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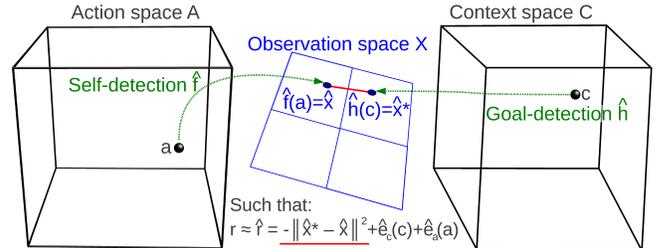

Fig. 2. Proposed learning formulation Latent Goal Analysis

We present theory results [7] that indeed *any reward or value function* $r(\mathbf{c}, \mathbf{a})/Q(\mathbf{c}, \mathbf{a})$ of actions $\mathbf{a}$ and contexts $\mathbf{c}$ can be explained by *latent goals* and action outcomes. Starting from a reinforcement learning problem as shown in Fig. 2, we show constructively how functions for both the detection of goals and the self-detection can be identified. Both functions project into a common and low-dimensional observation space, which is likewise identified. Within that space goal and action outcome can be compared, and their distance accounts for the originally observed reward or value. Our learning formulation allows for the first time to access goals and body schema in a coherent theoretical way. As an example of that fully generic framework, we shown in [4] that a pure information seeking reward based on visual saliency leads to a self-representation of the own hand, and a goal-detection of a close-by object.

Coming from the direction of goals, we have argued that the body schema needs to be considered at the same time because goals are meaningless without. In reverse, is the body schema meaningless without goals?

ACKNOWLEDGMENTS

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