GRASP: Emergence of Cognitive Grasping through Emulation, Introspection and Surprise.

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The aim of GRASP is the design of a cognitive system capable of performing grasping and manipulation tasks in open-ended environments, dealing with novelty, uncertainty and unforeseen situations. To meet the aim of the project, studying the problem of object manipulation and grasping will provide a theoretical and measurable basis for system design that is valid in both human and artificial systems. This is of utmost importance for the design of artificial cognitive systems that are to be deployed in real environments and interact with humans and other agents. Such systems need the ability to exploit the innate knowledge and self-understanding to gradually develop cognitive capabilities. To demonstrate the feasibility of our approach, we will instantiate, implement and evaluate our theories and hypotheses on robot systems with different embodiments and complexity.

GRASP will develop means for robotic systems to reason about graspable targets, to explore and investigate their physical properties and finally to make artificial hands grasp any object. To meet these objectives, we will use theoretical, computational and experimental studies to model skilled sensorimotor behaviour based on known principles governing grasping and manipulation tasks performed by humans. As widely recognised, to design and evaluate such a complex system, we need to integrate computational techniques from machine learning, computer vision, control theory and signal processing together with experimental frameworks that include real robotic and simulation tools that allow for a long-term, experimental control over sensory inputs and tasks. Hence, the objective of GRASP is to integrate findings from disciplines such as neuroscience, cognitive science, robotics, multimodal perception and machine learning to achieve a core cognitive capability: *Grasping any object by building up relations between task setting, embodied hand actions, object attributes, and contextual knowledge such that learnt grasps are extendable toward new, never seen objects in new situations.*

The key aspect is the emulation for retrieving of self-knowledge. This means moving from the classical perceive-act or act-perceive approach to the predict-act-perceive paradigm as indicated by findings from brain research and results of mental training in humans. The knowledge of grasping in humans can be used to provide the initial model of the grasping process that then has to be grounded through introspection to the specific embodiment. To achieve open-ended cognitive behaviour, we use surprise to steer the generation of grasping knowledge and modelling. As a consequence, GRASP sets out to fulfil five scientific and technical objectives:

1. ***Theory of Grasp Modelling*** -We will study the requirements and effects of the agent's embodiment on the situatedness, awareness, task and environment understanding and thus provide the means for adaptation and self-reasoning. Learning from human grasping examples will be used to predict and derive which part(s) of the space of all possible grasps can be realised with a specific artificial hand configuration.
2. ***Self- and Context-Awareness*** -We will investigate how an agent benefits from using tutor based and autonomous exploration together with physical modelling of the world to learn more about the possibilities and constraints offered by its embodiment. This will lead to ontology and new representations in the area of systems integration where we consider sensors, embodiment and the environment including other agents allowing for faster knowledge inference based on existing and new competences.
3. ***Curiosity and Surprise Driven Behaviour*** - We will show how the detection of an unexpected event or action is exploited to efficiently add new values, categories or dimensions to the grasping ontology while at the same time exploiting surprise to

bootstrap the learning process. Expectations are derived from the prediction of agent behaviour using the experiences gained from self-awareness or introspection.

4. ***Inferring new Grasping Strategies*** - We will use the ontology and acquired general knowledge to generate expectations for grasping and manipulation tasks as means of correction between the predicted and the actual state. This will allow adaptation to new objects and situations without the need for extensive re-programming.

5. ***Exploitation to Future Prosthesis, Industrial and Service Markets*** - Finally, we set out to exploit the theoretical findings by investigating the grasp mapping to different artificial hands. The objective is to learn how kinematical design and the number of DOFs influence dexterity and how to optimize the graspable sub-set of all possible grasps while minimising DOFs. This shall ultimately lead to efficient hand designs that are suitable for low cost production to aid as many handicapped persons as possible. It shall also influence future manufacturing of robotic hands useful to industrial as well as service-oriented enterprises.

Progress will be measured along two benchmarks as exemplars of industrial and home tasks:

- Emptying a box of industrial parts, and
- Emptying a basket of grocery items.