Research Statement

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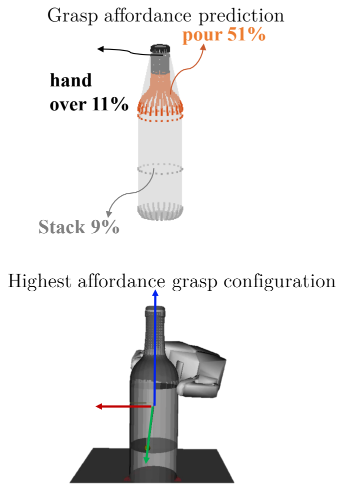
Video Summary:
http://bit.ly/r_statement
CV & Portfolio:
https://paolaardon.github.io/
Google Scholar Profile:
https://bit.ly/ardon_google_scholar

Research Contributions

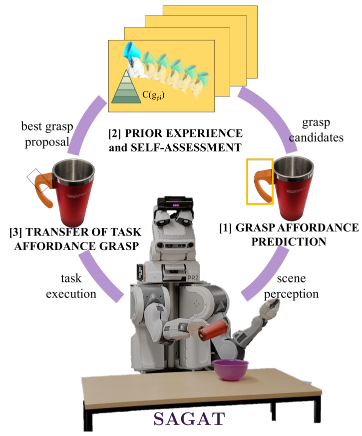
My doctoral research focuses on developing new methods that enable an artificial agent to grasp and manipulate objects autonomously. More specifically, I am using the concept of *affordances* to learn and generalise robot grasping and manipulation techniques. (Gibson) defined affordances as the ability of an agent to perform a certain action with an object in a given environment. By understanding the task, affordances provide the potential for an agent to effectively bridge perception to action. Prior research on object affordance detection is effective, however, among others, it has the following technical gaps: (i) the methods are limited to a single object↔affordance hypothesis, and (ii) they cannot guarantee task completion or any level of performance for the manipulation task. In my research, I started by addressing these two technical challenges and found that my solutions, besides building towards robot autonomy, have the potential to improve human-robot interaction tasks. As such, I summarise my research contributions as follows.

Generalising Robot Grasp Affordances



Understanding object affordances enables an autonomous agent to generalise manipulation tasks across different objects. The classical methodologies for grasp affordance recognition are effective, however, they are limited to a single object↔affordance hypothesis. To address this challenge, I developed an approach for detection and extraction of multiple grasp affordances on an object via visual input. I defined multiple object semantic attributes and presented them to participants in a user study to extract these attributes relation. Using the collected data, I encoded the relations in an knowledge base graph representation and learned the probability distribution of grasp affordances for an object using Markov Logic Networks. My method achieved reliable mappings of the predicted grasp affordances on the object by learning prototypical grasping patches from several examples (example on the right). Additionally, the proposal showed generalisation capabilities on grasp affordance prediction for new objects. Different stages of this research have been published in (ARSO'18; AAAIFS'18; TAROS'19; RA-L'19), and one paper was nominated for best paper award at (TAROS'19).

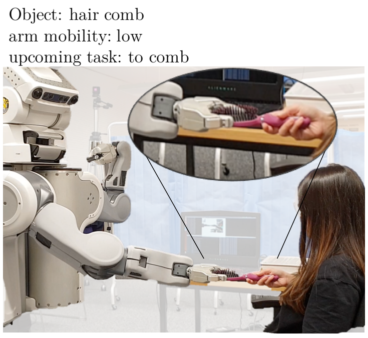
Self-Assessment of Grasp Affordance



Traditional approaches are driven by hypotheses on visual features rather than an indicator of a proposal's suitability for a task. Consequently, classical approaches cannot guarantee task completion or any level of performance when executing a task. In my research, I addressed this gap by creating a pipeline for self-assessment of grasp affordance transfer (SAGAT) based on prior experiences. My method visually detects a grasp affordance region to extract multiple robot grasp configuration candidates. Using these candidates, I forward simulate the outcome of executing the affordance task to analyse the relation between task outcome and grasp candidates. The relations are ranked by performance success with a heuristic confidence function and used to build a library of affordance task experiences. This library is later queried to perform one-shot transfer estimation of the best grasp configuration on new objects. Stages of this research have been published in (AAAIFS'18b; TAROS'19b; RA-L'19b; IROS'20), and one paper won the Advanced Robotics at Queen Mary (ARQ) best paper award at (TAROS'19b).

Affordance-aware Handovers with Human Arm Mobility Constraints

In the context of human-centred robotic applications, namely object handovers, understanding object grasp affordances allows an assistive agent to estimate the appropriateness of handing over object. This understanding is of particularly interest when the receiver has some level of arm mobility impairment. In an ongoing work, I addressed this challenge by proposing a *novel* method that generalises handover behaviours



to previously unseen objects, subject to the constraint of a user's arm mobility level. In my proposal, I designed a heuristic cost whose optimisation adapts object configurations considering receiver's with low arm mobility and their upcoming task. Then, to understand user preferences over handover configurations, with the help of a psychologist, I presented different handover methods, including my proposal, to users with different levels of arm mobility. The study showed that people's preferences are correlated to their arm mobility capacities. Then, I encapsulated these preferences in a statistical relational learner (SRL) that is able to find the most suitable handover configuration given a receiver's arm mobility and upcoming task. Part of this research has been submitted to (RA-L'21).

Future Research Plans

My doctoral research seeks to improve classical robotic grasping by using machine learning reasoning techniques. In particular, I focused on technical gaps to improve autonomy for grasp and manipulation planning and then leveraged my solutions to endow a robot to 'intelligently' interact with objects and other agents (e.g., humans). Looking forward, I envision making a social impact by continuing my work on robust and reliable techniques that facilitate a robot to autonomously perform grasping and manipulation tasks in home environments. To achieve such autonomous behaviours, I believe in the importance of multidisciplinary collaborations with other areas, e.g., physiology and social sciences, to facilitate the human-robot interaction aspects of the research. To this end and motivated by my expertise, I visualise a research team working together towards autonomous assistive agents by focusing on the following challenges.

Managing Multiple Sequential Tasks

Following my research presented in (IROS'20), one of my research interests lies in finding synergies between affordances (semantic actions) and behavioral actions (trajectories) for task planing in unstructured environments. For example, imagine a robot following a recipe. The robot needs to perform different actions with different objects, such as pouring and stirring, among others. In order to achieve an autonomous system that performs sequential manipulation tasks, there needs to be progress towards the study of integrating sequential semantic and motion tasks. A step in this direction will allow sets of actions and grasps to be predicted when dealing with multiple correlated objects in the scene. Developing planning techniques that connect motion with semantic actions would potentially improve the extraction of tractable tasks descriptions for the robot. This sequential task understanding will not only enable a robot to operate alone but also in collaboration with humans, as well as with other robotic systems.

Understanding Task Deployment Context

Inspired by my previous work in (RA-L'19; IROS'20; RA-L'21), I intend to pursue future research to achieve adaptable robotic manipulation behaviours. For example, the robot's grasp selection and motion trajectory should differ when the robot is tasked to pour from a glass vs. when tasked with handing over the same glass to another agent, so they can proceed with the pouring. To achieve such a selective behaviour, additionally to task understanding, the robot should consider the task specification constraints related to pruning grasping configurations and trajectory motions to achieve the different tasks. Little to no research has been devoted towards developing machine learning reasoning techniques that allow a robot to distinguish between tasks constraints. This direction of study would allow an assistive agent to improve trustworthiness by discerning the constraints related to performing different tasks, and open doors to other branches of investigation such as online dynamic task allocation when in collaborative tasks.

Affordance-aware Tasks for Human-Robot Collaboration

When in a collaboration task, a robot should be able to read and adapt behaviours online to adapt to human's comfort. For example, to assess comfort end-state, in ongoing research (RA-L'21), I started to explore offline learning solutions to adapt object handovers to populations with low arm mobility. I envision that eliciting from humans what robots can or should do, as well as extracting human factors such as gaze and kinematic mappings for trajectory and non-verbal cues, will facilitate the creation of human intentions representative models. The creation of such models will ease the robot's ability to adapt online when performing affordance-aware tasks, not only to accommodate to the human's mobility capacities but also to improve human's comfort and avoid working at cross-purposes.

List of Publications

[AAAIFS'18] **Ardón, P.**, È. Pairet, S. Ramamoorthy, and K. Lohan. Towards robust grasps: Using the environment semantics for robotic object affordances. In *AAAI Fall Symposium. Reasoning and Learning in Real-World Systems for Long-Term Autonomy*. AAAI Press, 2018.

[AAAIFS'18b] E. Pairet, **Ardón P.**. , F. Broz, M. Mistry, and Y. Petillot. Learning and composing primitive skills for generalisable dual-arm manipulation. In *AAAI Fall Symposium: Reasoning and Learning in Real World Systems for Long-term Autonomy*, 2018.

[ARSO'18] **Ardón, P.**, S. Ramamoorthy, and K. Lohan. Object affordances by inferring on the surroundings. In *IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO)*, Sept 2018. in press.

[Gibson] J. J. Gibson. The senses considered as perceptual systems. Houghton Mifflin, 1966.

[HRI'19] È. Pairet, **Ardón, P.**, X. Liu, H. Lopes, J.and Hastie, and K. Lohan. A digital twin for human-robot interaction. In *14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, pages 372–372. IEEE, 2019.

[HRI'20] D. Robb, M. I. Ahmad, C. Tiseo, A. C. Aracri, S.and McConnell, V. Page, C. Dondrup, F. J. Chiyah Garcia, H. Nguyen, È. Pairet, **Ardón, P.**, et al. Robots in the danger zone: Exploring public perception through engagement. In *Proceedings of the ACM/IEEE International Conference on Human-Robot Interaction*, pages 93–102, 2020.

[ICAPS'20] Y. Carreno, E. Pairet, **Ardón, P.**, Y. Petillot, and R. Petrick. Task allocation and planning for offshore mission automation. In *System demonstration at International Conference on Automated Planning and Scheduling (ICAPS)*, 2020.

[IROS'20] **Ardón, P.**, È. Pairet, Y. Petillot, R. P. Petrick, S. Ramamoorthy, and K. Lohan. Self-assessment of grasp affordance transfer. In *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2020.

[RA-L'19] **Ardón, P.**, È. Pairet, R. P. Petrick, S. Ramamoorthy, and K. Lohan. Learning grasp affordance reasoning through semantic relations. *IEEE Robotics and Automation Letters, presented in IROS*, 4(4):4571–4578, 2019.

[RA-L'19b] È. Pairet, **Ardón, P.**, M. Mistry, and Y. Petillot. Learning generalisable coupling terms for obstacle avoidance via low-dimensional geometric descriptors. *IEEE Robotics and Automation Letters, presented in IROS*, 2019.

[RA-L'21] P. Ardón, M. E. Cabrera, È. Pairet, R. Petrick, S. Ramamoorthy, K. S. Lohan, and M. Cakmak. Affordance-aware handovers with human arm mobility constraints. IEEE, 2021. DOI: 10.1109/LRA.2021.3062808.

[Springer'18] **Ardón, P.**, M. Dragone, and M. S. Erden. Reaching and grasping of objects by humanoid robots through visual servoing. In *International Conference on Human Haptic Sensing and Touch Enabled Computer Applications*, pages 353–365. Springer, 2018.

[Springer'20] K. Lohan, M. I. Ahmad, C. Dondrup, **Ardón, P.**, È. Pairet, and A. Vinciarelli. Adapting movements and behaviour to favour communication in human-robot interaction. In *Modelling Human Motion*, pages 271–297. Springer, 2020.

[T-RO'20 under review] **Ardón, P.**, È. Pairet, K. Lohan, S. Ramamoorthy, and R. Petrick. Affordances in robotic tasks–a survey. *arXiv preprint arXiv:2004.07400. Under review at Transactions on Robotics.*, 2020.

[TAROS'19b] È. Pairet, **Ardón, P.**, M. Mistry, and Y. Petillot. Learning and composing primitive skills for dual-arm manipulation. In *Annual Conference Towards Autonomous Robotic Systems.*, pages 65–77. Springer, 2019. **Advanced Robotics at Queen Mary (ARQ) best paper award**.

[TAROS'19] **Ardón, P.**, È. Pairet, R. Petrick, S. Ramamoorthy, and K. Lohan. Reasoning on grasp-action affordances. In *Conference Towards Autonomous Robotic Systems*. Springer, 2019. **Finalist for best paper award**.