Introduction

This document describes a master project/thesis proposal in the context of the AILARON [1], which targets the imaging, processing and classification of plankton images to enable autonomous sampling on an Autonomous Underwater Vehicle (AUV). An AUV is an untethered and propelled mobile robot that is a critical piece of equipment for obtaining measurements underwater; data collected can then be transmitted either when the vehicle is on the surface, or when it returns to shore (Fig. 1).

The use of advanced deliberative methods in Artificial Intelligence (AI) is novel and emerging. And therefore substantial scope for engaging in a wide variety of research and innovation exists. In Norway NTNU is the only institution engaging in such research activities. This can ultimately lead to very viable employment opportunities in Norway or elsewhere.

The development and integration of AI/Planning strategies plays an important role in shaping mission profiles for the AUV that comply with the purpose of the research project. Traditional ship-based observations are not continuous, disturb the upper water layer significantly and cannot scale across space and time. Reliance on such methods needs to be reduced by augmentation with recent advances in Robotics and AI research which enable autonomous systems to make decisions onboard while adaptively making continuous measurements to provide biologists with data.

Planning is an abstraction layer standing above control methods and generating plans, meant as timely defined actions sequences, for desired outcomes and intents [2]. In doing so, these sequences are synthesized, transforming the initial state of a robot to a state satisfying required goals. By incremental decomposition of these goals, automated planning and execution of those plans, lifts the command/control of robotic platforms towards human comprehension and validation. Acquiring the model of the environment and actions...
(a) T-REX is an advanced temporal constraint-based planning and execution framework. It consists of coordinated engines called reactors each of which can focus exclusively on a subproblem to solve deterministically.

(b) A typical model-based AI Planner consists of a plan database, a search engine and a domain model. The core engine and database are robust constructs; only the model is required to be crafted towards a specific domain.

Figure 2: Elements of T-REX and the essentials of a generalized AI planning system.

is done through a Knowledge Engineering (KE) process that transforms the real world into a symbolic representation such that the model is consistent, accurate, complete and operational. KE is a crucial task that faces the continuously changing and dynamic nature of the environment itself.

The Teleo-Reactive EXecutive (T-REX) in particular is unique in operational oceanography. It is both reactive as well as deliberative in continuous plan synthesis and execution. Sustained and continuous autonomous control is still an open challenge. Generated plans would likely be not valid during sustained exploration, relying on shore-based operators for support with new or modified goals. Therefore, the system has to be self aware, robust to operational failures and provided with the autonomy to generate its own goals. These opens up are a rich and challenging set of challenges that the candidate will be asked to investigate.

T-REX has had significant legacy in space with NASA, as well as in marine robotics and science and is the only deliberative control framework in operational oceanography.

Project workflow

Selected student(s) will first become familiar with the literature portion targeting real-world AI/Planning applications and results. The first part of the thesis involves a robust formalization of the agent model. Modeling is of primary importance for the planner to come up with feasible sequences of actions. The model has to be simple and needs to be shaped
according to the targeted application. While modeling, the candidate needs to be aware of the capabilities of the vehicle it will be embedded in, in order to best align with the harmony of the system. Together with a model of the agent, a well-defined set of actions has to be stated to support the planning/execution process. Modeling translates in the format of well-established language formalisms, whose effectiveness has been proven for such applications. Once a model is built, its integration in T-REX can follow. Integration and simulations constitute the second phase. The simulation of a wide spectrum of missions will give an indication about the quality of the model. Finally, planning/execution capabilities will be field-tested, in Trondheimsfjord, according to the AILARON project schedule.

Specific project ideas are as follows:

**Domain Modeling:** This is a key task associated with describing the physics of the robot’s tasking and execution in a complex and uncertain real-world environment. Not only does the model describe how various subsystems work, but also how they interact with each other. The EUROPA$_2$ planner at the heart of T-REX uses a higher-order language of constraints to describe how the system can construct plans embedded on the vehicle and how to instantiate them.

**Sensor integration:** A planner works on the sense-plan-act loop. For the planner to synthesize plans for execution, it needs to be aware of the environment in which the robotic vehicle is placed in. Sensing actions are performed independently and the sensing streams are sub-sampled and fed to the planner. Integrating such sensory streams are therefore important for the planner to work.

**Alternative information sources:** While sensors form the core of how the planner makes situated-ness viable, additional streams of information, which could provide context or subtle command directives, such as compact models of the environment, could be embedded within T-REX.

**Candidate responsibilities**

The selected student(s) will be responsible for the design, modeling and integration of planning/execution strategies that equip the AUV with the ability to autonomously synthesize and execute plans embedded on a mobile robot. This process makes use of the open-source T-REX framework. The candidate is responsible for its integration on the unmanned platform and for its relation/communication with the components already embedded. His/her work is considered to be concluded once the implementation of an AI-based controller is available for usage within the scope of the AILARON project.

**Required skills**

- active interest in robotics and autonomous systems
- intermediate to advanced knowledge of C++, Python
- must have familiarity with UNIX-based systems (CLI operations and usage as basic requirement)
• basic bash programming is a plus!
• appreciation and interest in marine science and oceanography is a plus

We encourage students with strong programming skills coming from any discipline with a keen desire to make an impact and publish results to apply. More information concerning the LSTS toolchain (GLUED, Dune, Neptus, IMC) are available in [13].

References

Onboard AI Planning for autonomous plankton-based imaging and learning

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