A Middleware based Framework for Multi-Robot Application Development

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Abstract. The development of multi-robot applications represents an iterative process where hardware and software have to be adjusted among each other and in relation to the environment. For large scale swarms with numerous mobile systems changes on the hardware and the deployment of software is extensive and laborious process. The combination of virtual and real robots in our framework allows a comfortable examination of software and hardware components in a predefined and reproducible test bed at each project stage.
The demonstration scenario illustrates the integration of our middleware and emphasises the possibilities of the framework in the development process and during the life cycle.

1 Introduction

The design process of robotic applications includes a broad field of challenges in different disciplines that are related in a complex way. For instance, the reaction of a mobile system on obstacles is determined by its kind of sensors, their positions on the robot, its application algorithm, the kinematical configuration of the system, motor power etc. As a result developers tend to decompose the system of hardware and software in easy to manage, separated substructures according to each development stage. Such substructures are usually implemented in individual and mostly inflexible experimental setups with non uniform architecture and/or communication models. For instance a special tool is used for testing sensor fusion algorithms and another for controller design. Thus, for the integration of different subsystems such detached solutions needs additional effort.

In contrast, our framework provides a uniform communication abstraction based on our middleware FAMOUSO (**F**amily of **A**daptive **M**iddleware for autonom**OU**s **S**entient **O**bjects). It allows the seamless integration and combination of various components of both real hardware (sensors, controllers etc.) and simulated elements (environments, virtual sensors, robots). FAMOUSO handles the event-based communication in a publisher/subscriber fashion [Sch08, CKV04]. FAMOUSO offers a common programming interface for C, C++, Matlab/Simulink, Python and Java on different networks like CAN, TCP, 802.15.4, AWDS and UDP-Multicast. In a typical development cycle based on Matlab/Simulink, developers use the functionalities for simulation and control design of the mechatronic components at a first step. Afterwards, they connect their application with real hardware via FAMOUSO and validate the simulation results in Hardware-in-the-Loop scenarios [KSZ+08]. The last step could be the code generation for the robot platforms. In all development steps, FAMOUSO handles the communication.

For multi-robot applications the advantages are more extensive. In a simulation setup, developers handle a lot of participating robots very comfortably. Effective application development is supported by simulating the environment, robots and sensors. However, simulations have to be validated on real hardware. At this point, developers identify quite often the assumptions made in the simulation stage as non realistic. Hence, they start an iterative process with more appropriate models and parameters. Consequently, a parallel validation without additional effort is helpful.

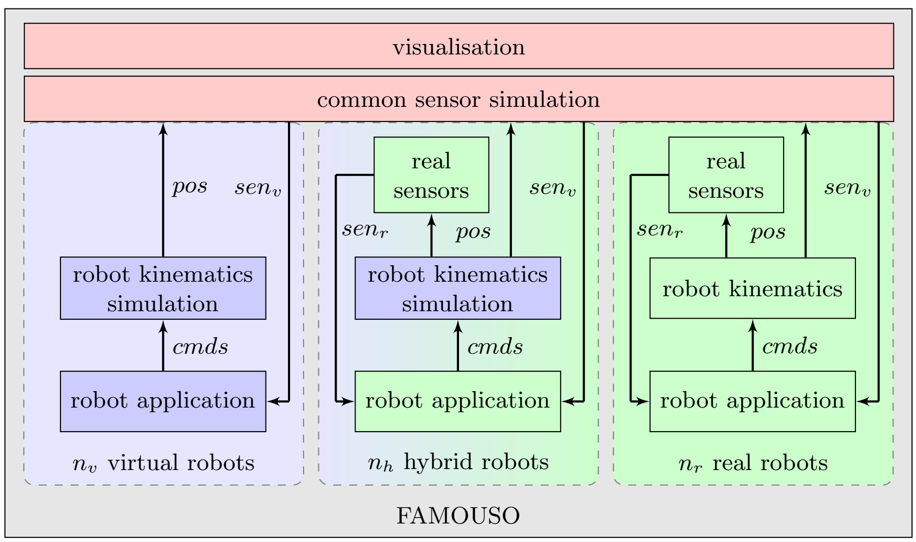

Fig. 1. Framework structure for multi-robot applications

The sketched development flow leads to a variety of scenarios. Figure 1 illustrates different combinations of virtual and real parts working seamlessly together. On the left, an entire simulation of n_v robots consists of a dynamic model and the robot application which communicates with the common sensor simulation. On the right, n_r real robots are integrated. They use the information of additional virtual sensors to observe the virtual environment and virtual robots. Between these both worlds different variations are possible. In the middle of Figure 1 a real robot controller is connected to a number of real sensors whereas the system dynamic is simulated. This combination of simulation and real hardware offered by our framework allows large scale, realistic scenarios with minor hardware effort. More specific validations are possible due to the coexistence of simulated reproducible sensor data and real controllers and actuators. In the opposite direction real sensors perceive real obstacles and communicate this information into the virtual environment.

2 Demonstration setup

The demonstration setup consists of two laptops and one real robot. We show the advantages of the middleware integration and the possibilities of our framework by presenting the realisation of the described scenario from Figure 1.

Therefore, different equipped virtual robots drive randomly in a simulated environment. The dynamics of the simulated robots is realised in a Simulink model. The applications – only simple collision avoidance – control robots movement. Additionally, a real mobile system goes around in the virtual environment. It consumes the virtual and real sensor information, calculates a path, follows them and gives the position to the visualisation. By simulating obstacles in front of virtual/real sensors the robots react correct in the virtual environment as well as in reality. The simplicity of variations of the used simulated robots, kinematical models or virtual environment configurations distinguishes the capabilities of our framework.

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