Joint Lab
Künstliche Intelligenz
& Data Science

Reconfigurable ROS Nodes for Modular Agricultural Robots

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What is Reconfiguration?

- Reconfiguration refers to multiple things in this context
  - 1. The addition or removal of physical robot modules
  - 2. Adapting and migrating software modules
  - 3. The reconfiguration of reconfigurable compute hardware (FPGA), adapting the hardware to the needed algorithm

Modular Robots in the Agricultural Context

- **Long Deployments** Agricultural robots need to be able to perform their tasks for extended amounts of time
- **Independence** The robots should be able to operate without constant supervision and in remote locations
- **Diverse Taskset** The robots are employed in a number of different tasks and should be able to specialize and adapt accordingly
- **Fault Tolerance** The long and independent operations of the robots require high fault tolerance, so the system can continue to operate even when unexpected conditions occur

The Ideal Modular Robot

- **Detect and adapt to equipped modules immediately**
- **Simple modules** Minimal pre-configuration is needed for modules
- **Algorithmic adaptability** The robot should choose optimal algorithms depending on the detected hardware
  - **Energy efficiency**
  - **High performance**
  - **Optimal component use** Choose the optimal algorithm for the currently equipped sensors/components
- **Reconfigure compute** The available compute hardware should be reconfigured according to the optimal configuration
  - **FPGA reconfiguration**
  - **Activation/Deactivation**
  - **Integrate newly added compute components**
  - **Migrate algorithms between compute components**
  - **Integrate heterogeneous compute components**
- **Topology detection** Detect the topology of the network automatically, to allow for efficient handling of the communication
- **Security** Added modules should be verified
- **Easy to develop** The workflow should allow developers to focus on other problems than the modularity

Challenges

Compute Cost

Is the compute cost just directly associated with the number of CPU cycles spent each second? If so, how to determine this value in the first place? What about memory and energy efficiency?

This becomes even more complicated when multiple different architectures are involved. How do CPU cycles relate to GPU cycles or FPGA chip resources? How to weigh the hardware expenses?

Performance Estimation

Estimating the performance of different software modules used for different components is also a challenge. For example, it is unclear how to compare the accuracy of the visual processing with the accuracy of the trajectory planning.
Ultimately we care about the task-related performance of the robot, but we can't measure all possible combinations. As such it is unclear how the resources should be distributed across modules.

Mapping Modules

If performance and cost estimations of different modules are available, the configuration must be determined. Based on the available modules a procedure must run to figure out the optimal configuration.

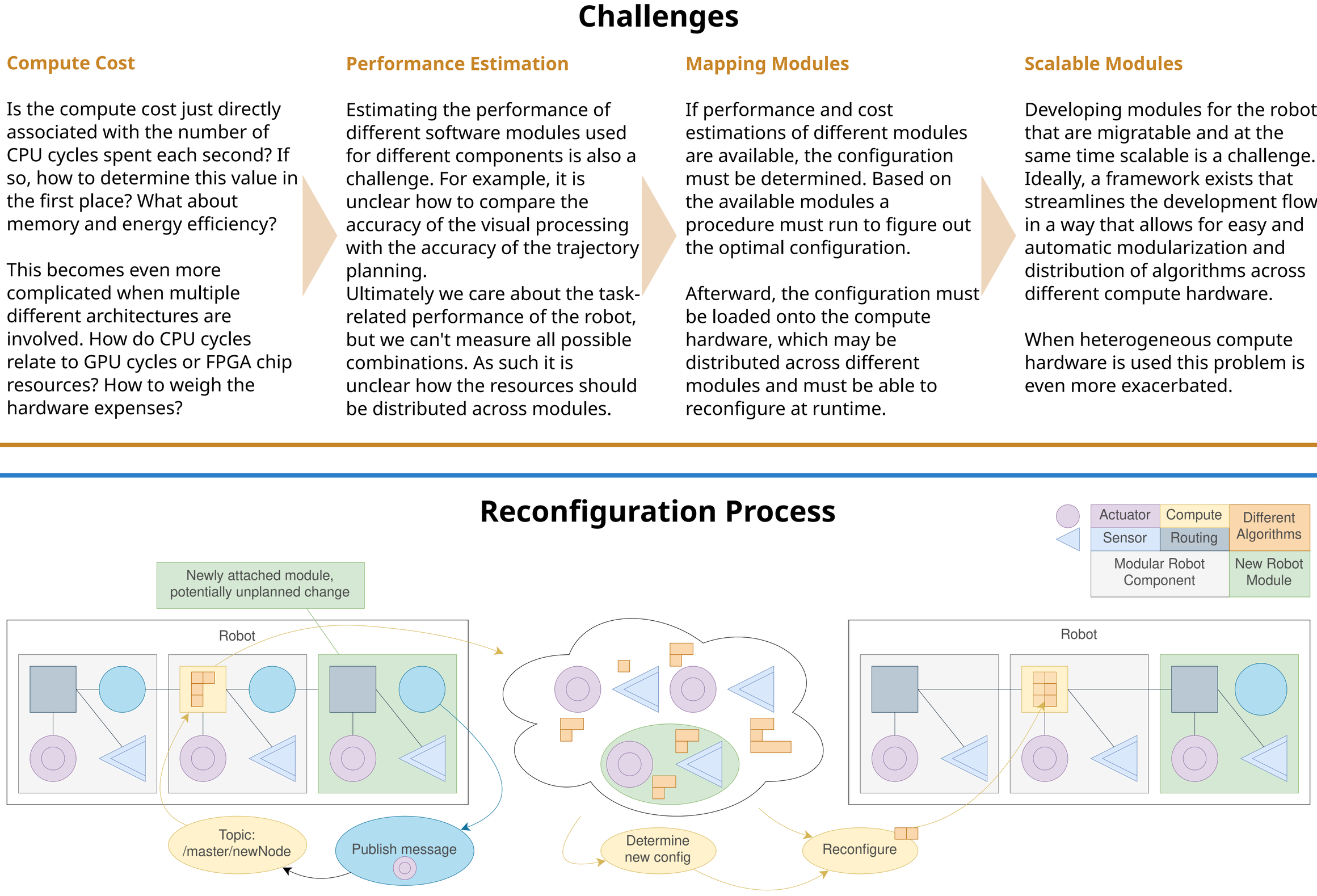
Afterward, the configuration must be loaded onto the compute hardware, which may be distributed across different modules and must be able to reconfigure at runtime.

Scalable Modules

Developing modules for the robot that are migratable and at the same time scalable is a challenge. Ideally, a framework exists that streamlines the development flow in a way that allows for easy and automatic modularization and distribution of algorithms across different compute hardware.

When heterogeneous compute hardware is used this problem is even more exacerbated.

Reconfiguration Process



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This is just the first step, more to come soon:
https://www.jl-ki-ds.uni-osnabrueck.de/ueber_uns/graduiertenkolleg.html