Incremental Component-Based Construction and Verification of a Robotic System

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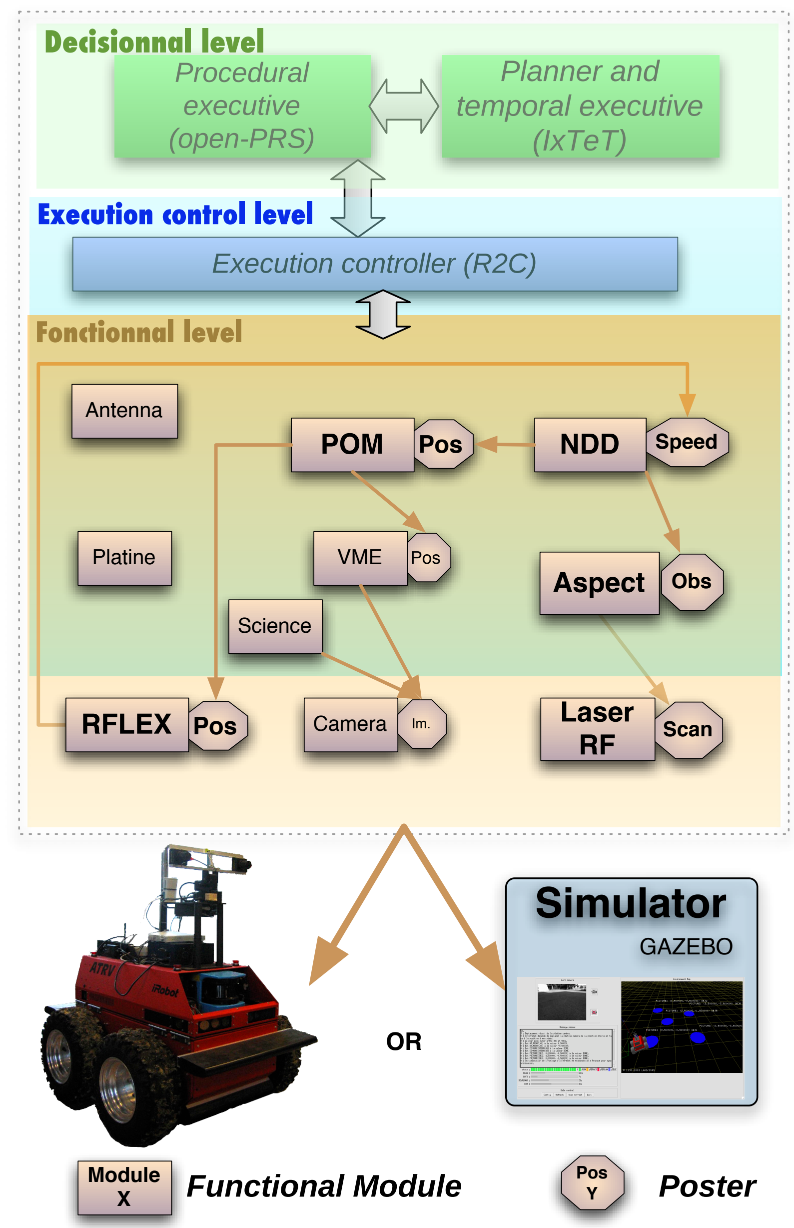
Control Architectures of Robots 2007

LAAS Architecture

- Functional Level: modules developed using GenoM; provide *services* and *posters*
- Navigation Loop:
  Laser + Aspect + NDD + RFLEX
- Centralized execution control: *R2C*, safety constraints and rules



BIP
Behavior Interaction Priorities

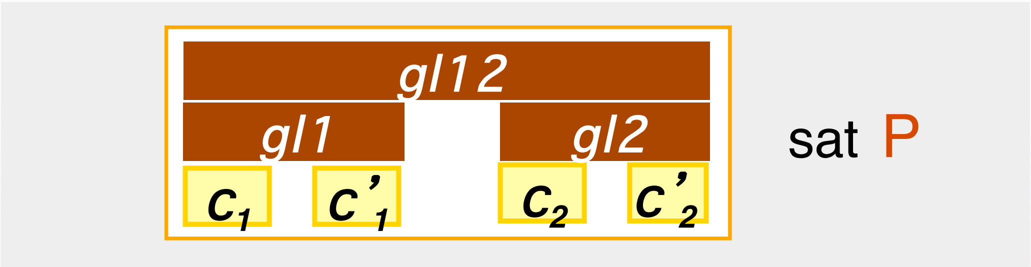
- Complex systems are built by assembling components (building-blocks)
- Components are systems characterized by their interface, an abstraction that is adequate for composition and reuse
- Large components are obtained by "gluing" together simpler ones

Component-based construction

- Develop a *rigorous* and *general basis* for real-time system design and implementation
- Concept of component and associated composition operators for *incremental* description and *correctness by construction*
- Concept for real-time architecture *encompassing heterogeneity*, paradigms and styles of computation
- *Automated* support for component *integration* and *generation* of *glue code meeting given requirements*

Formal framework

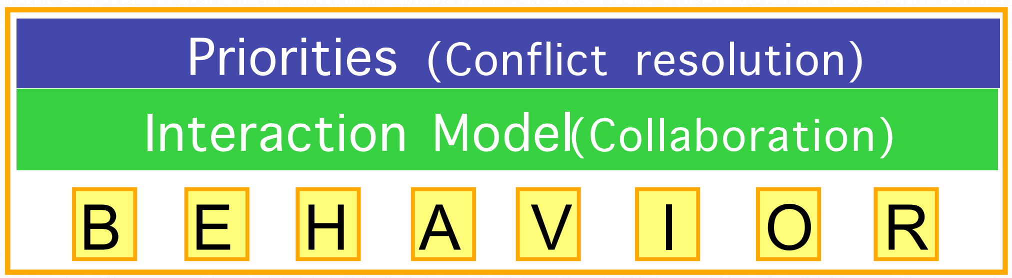
- Build a component *C* satisfying a given property *P* from :
  - $\mathcal{C}$ a set of atomic components modeling behavior
  - $\mathcal{GL}$ a set of glue operators on components



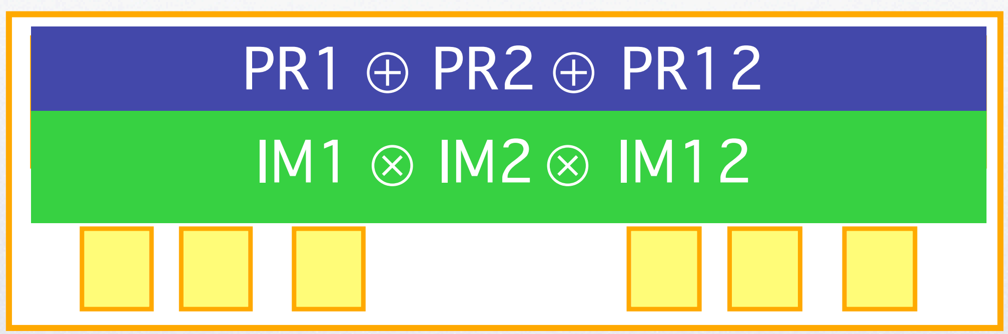
- Glue operators
  - model mechanisms used for communication and control such as protocols, controllers, buses...
  - restrict the behavior of their arguments

The BIP Framework

Layered component model

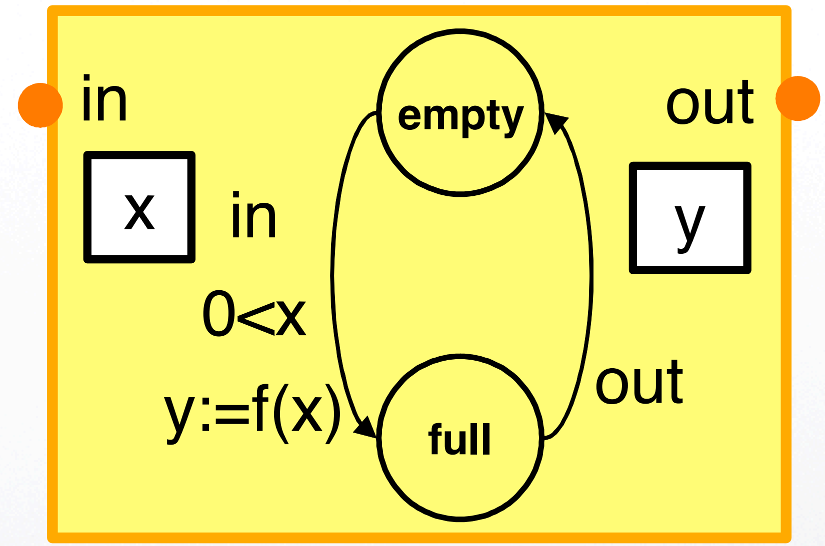


Composition (incremental description)



BIP: Behavior

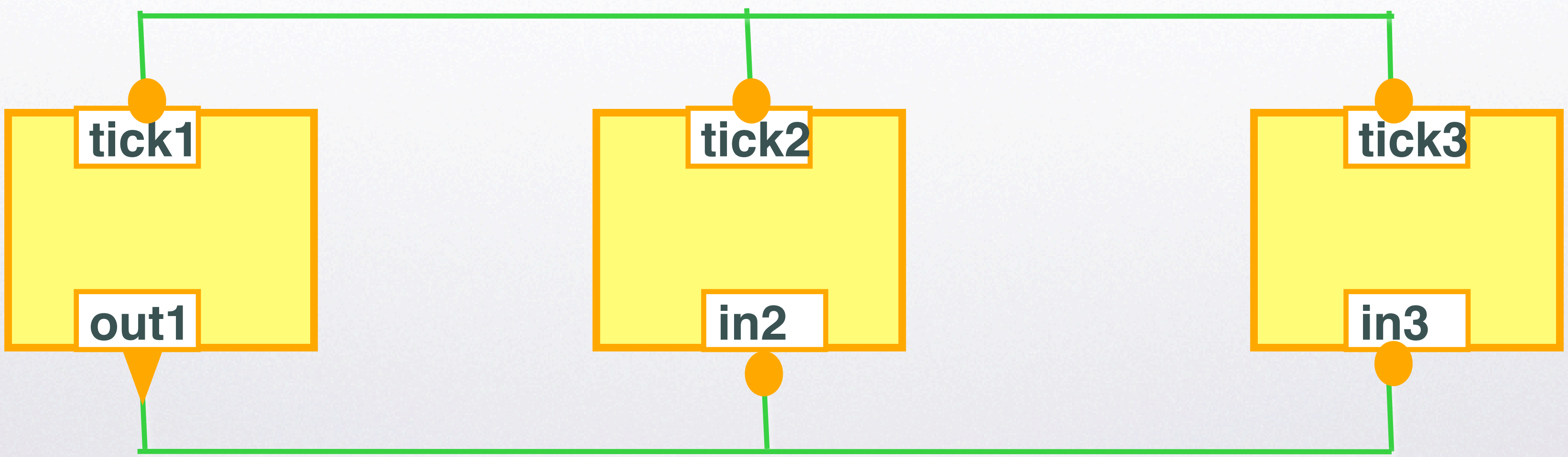
- An atomic component has
  - a set of ports P, for interaction with other comp.
  - a set of control states S
  - a set of variables V
  - a set of transitions of the form :
    - p is a port,
    - g is a guard, boolean expression on V,
    - f is a function on V (block of code)



$$s1 \xrightarrow{p,\ g,\ f} s2$$

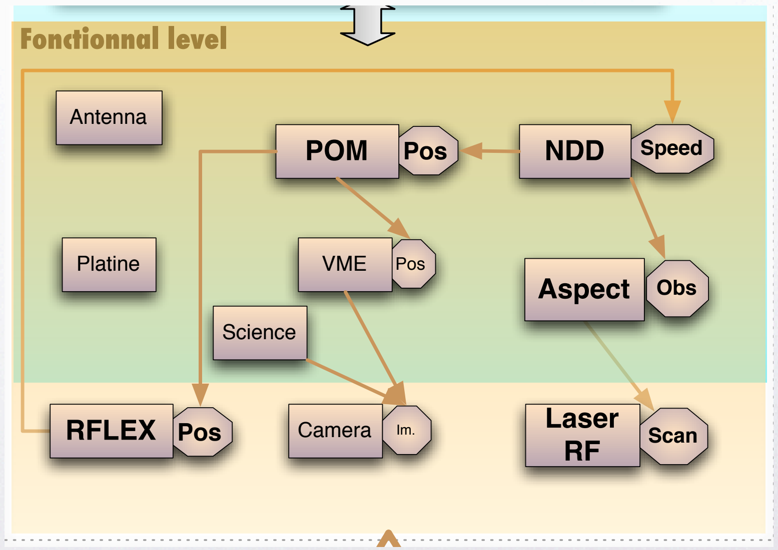
BIP : Interaction

- A connector is a set of ports that can be involved in an interaction
- Port attributes (*complete, incomplete*) are used to distinguish between *broadcast* and *rendezvous*
- Interactions: {tick1,tick2,tick3}{out1}{out1,in2}{out1,in2,in3}

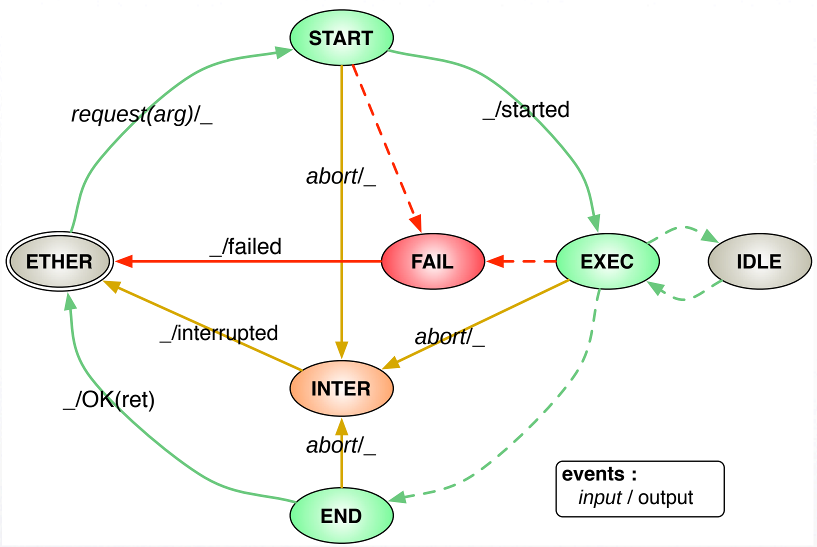


Componentization of the functional level

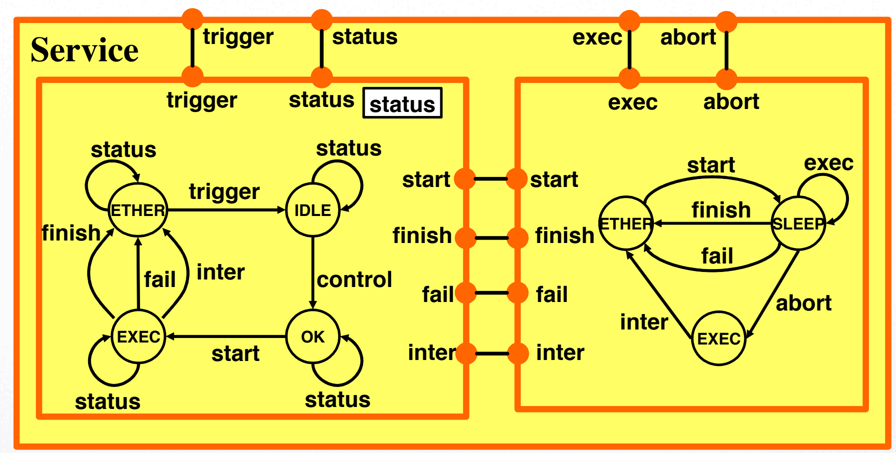
- Functional Level ::= Module+
- Module ::= Service+ . Control Task . Poster+
- Service ::= Execution Task . Activity
- Control Task ::= Timer . Scheduler Activity



BIP model of a service

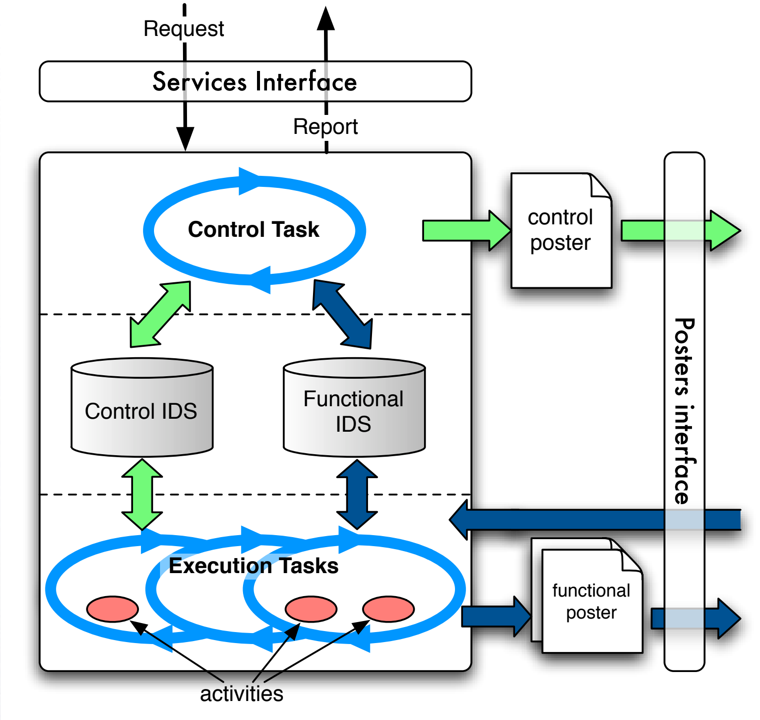


GenoM

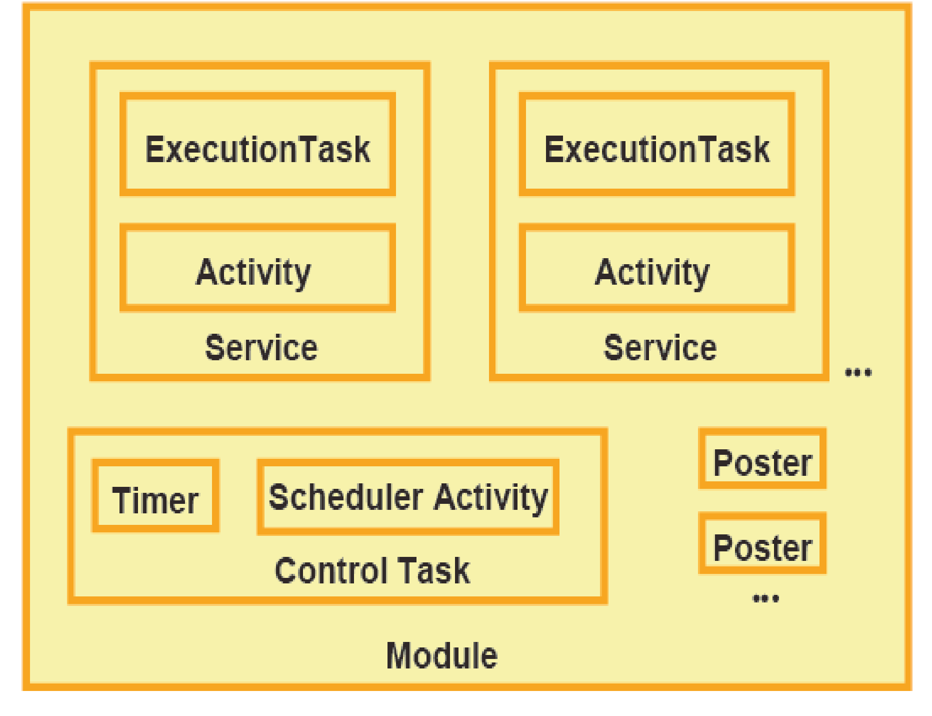


BIP

BIP model of a module

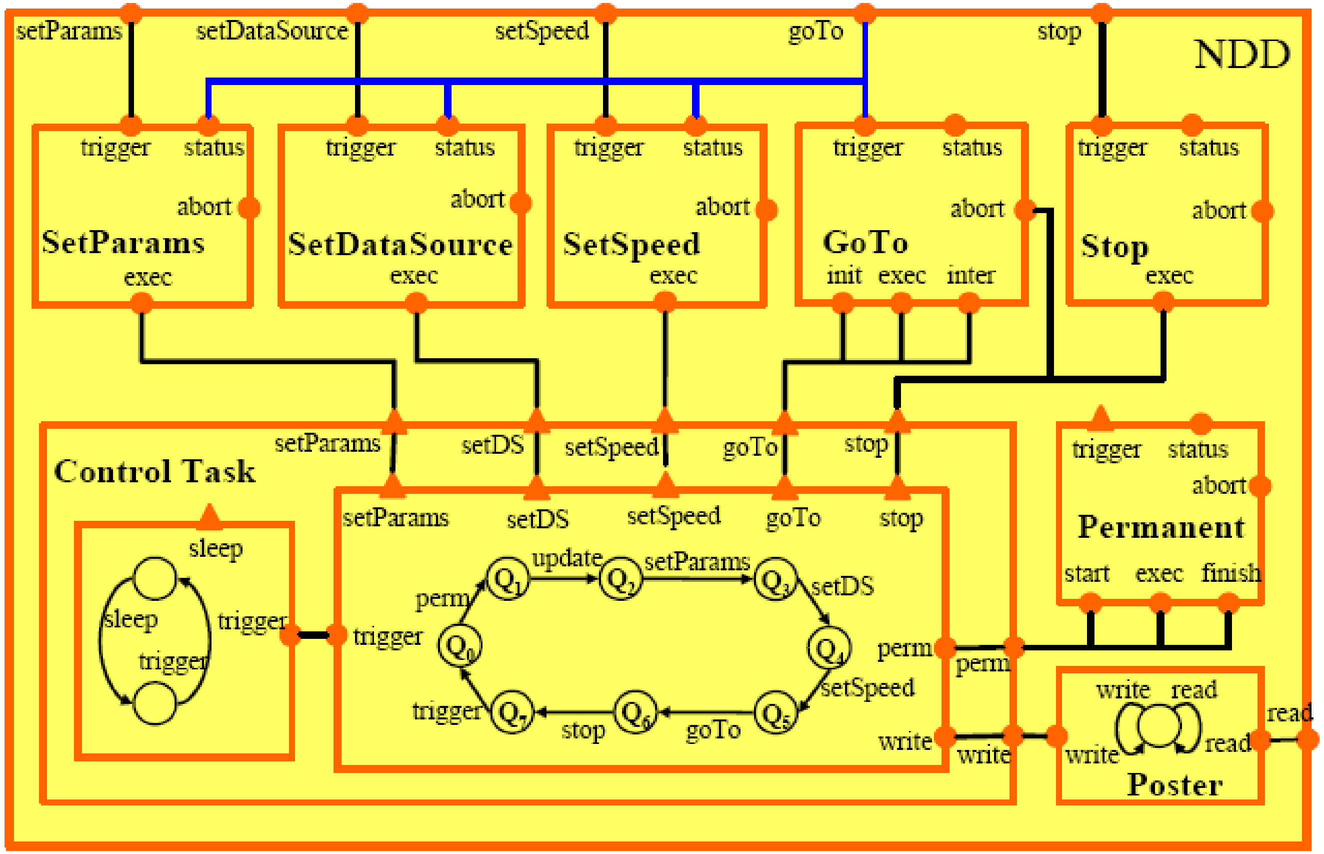


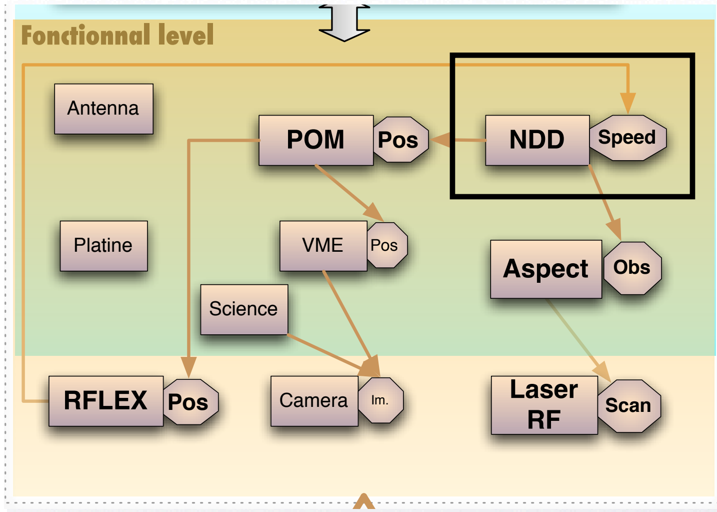
GenoM



BIP

BIP model of the NDD module





Execution

- Generation of a multithreaded BIP engine
- Executes interactions → functions called in a "GenoM" library
- Poster data managed via GenoM posterLib and shared memory
- Request and reports sent via mailboxes

  ⇒ interfaces with tcl, OpenPRS, test programs...

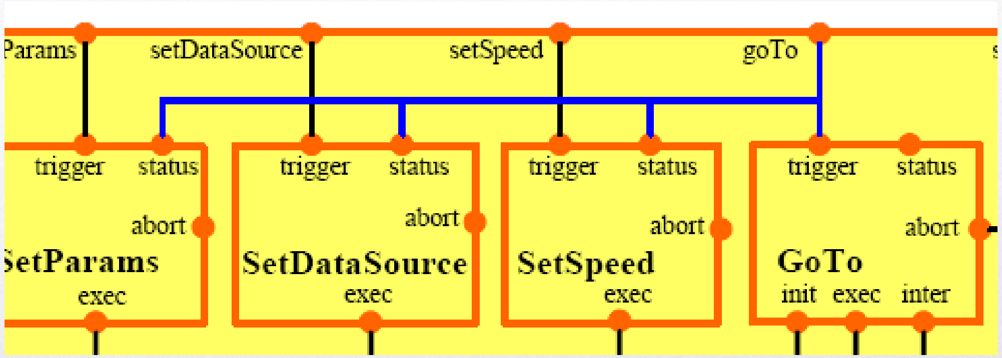
Execution control

- Constraints modeled as connectors

  see `goTo.trigger` *connector*

- Observers for on-line safety properties

  time constraints violation



Verification

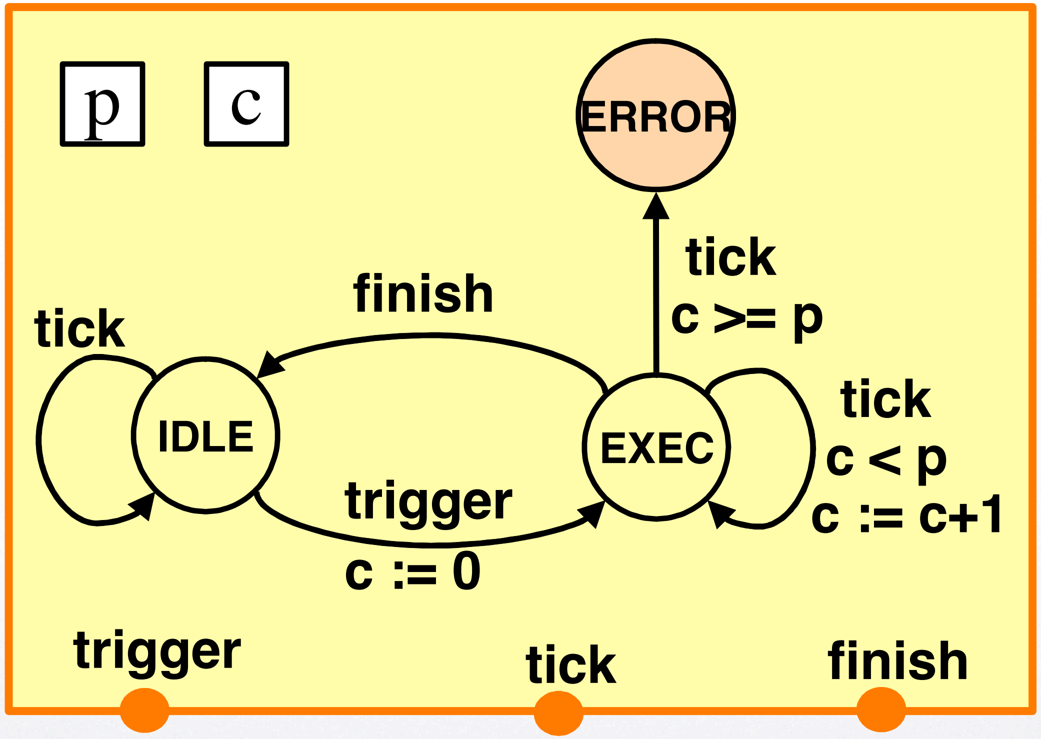
- Deadlocks
- Model-Checking

  e.g. verify that goTo.trigger is always executed after SetX services are complete

- Time properties

  Observers representing the desire properties; used offline in exploration to verify the property, and online for monitoring

NDD period verification

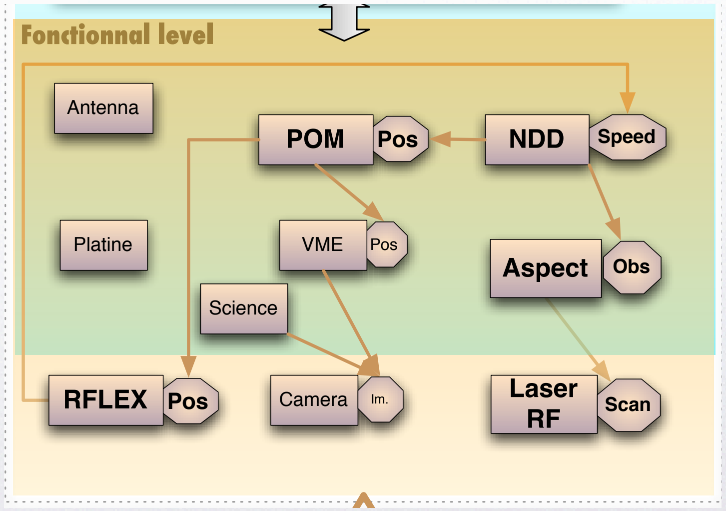


Ongoing work

- Modeling of other modules:

  Aspect, Laser, RFLEX(, PoM) $\Rightarrow$ *navigation loop*

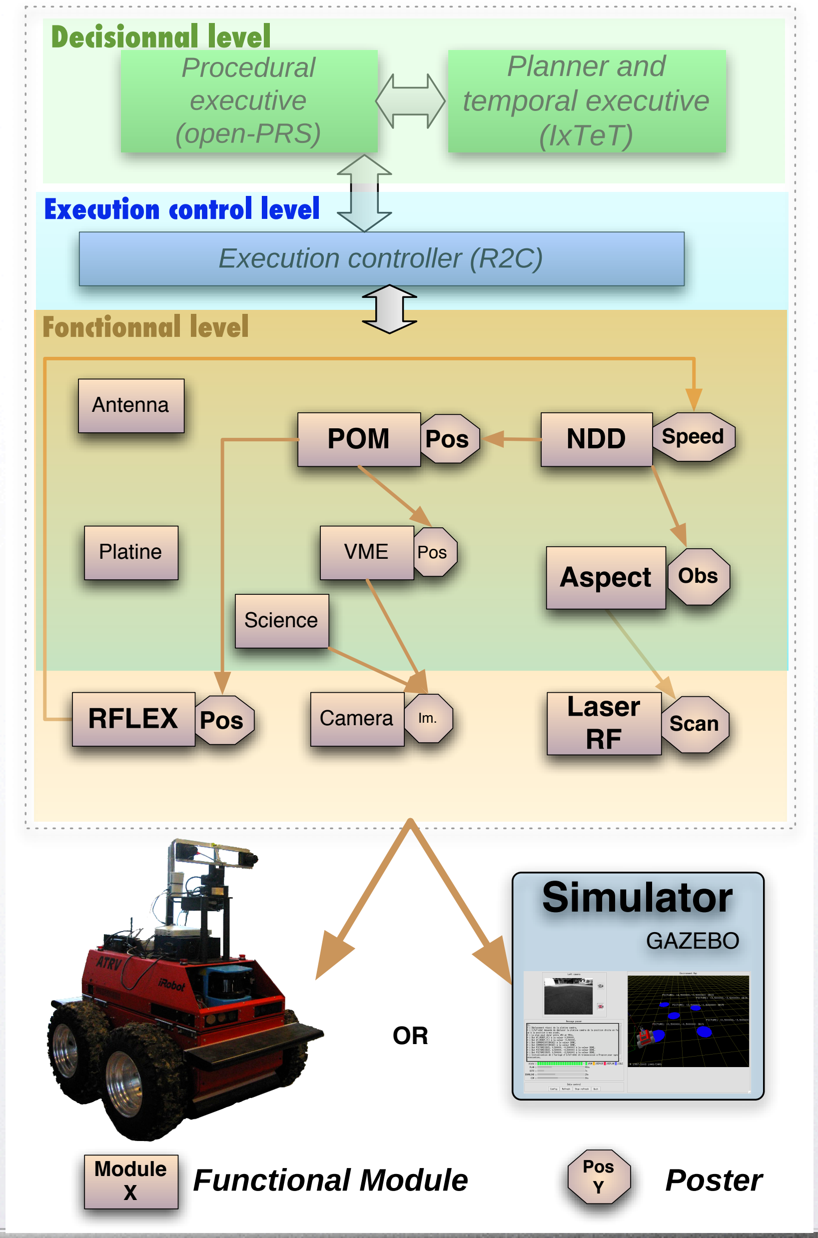
- Preparation of associated libraries for integration within BIP modules



Ongoing work

- **Constraints:**

  NDD navigation (*exec*) possible only if PoM has been launched (*Pos* poster contains a relevant position)

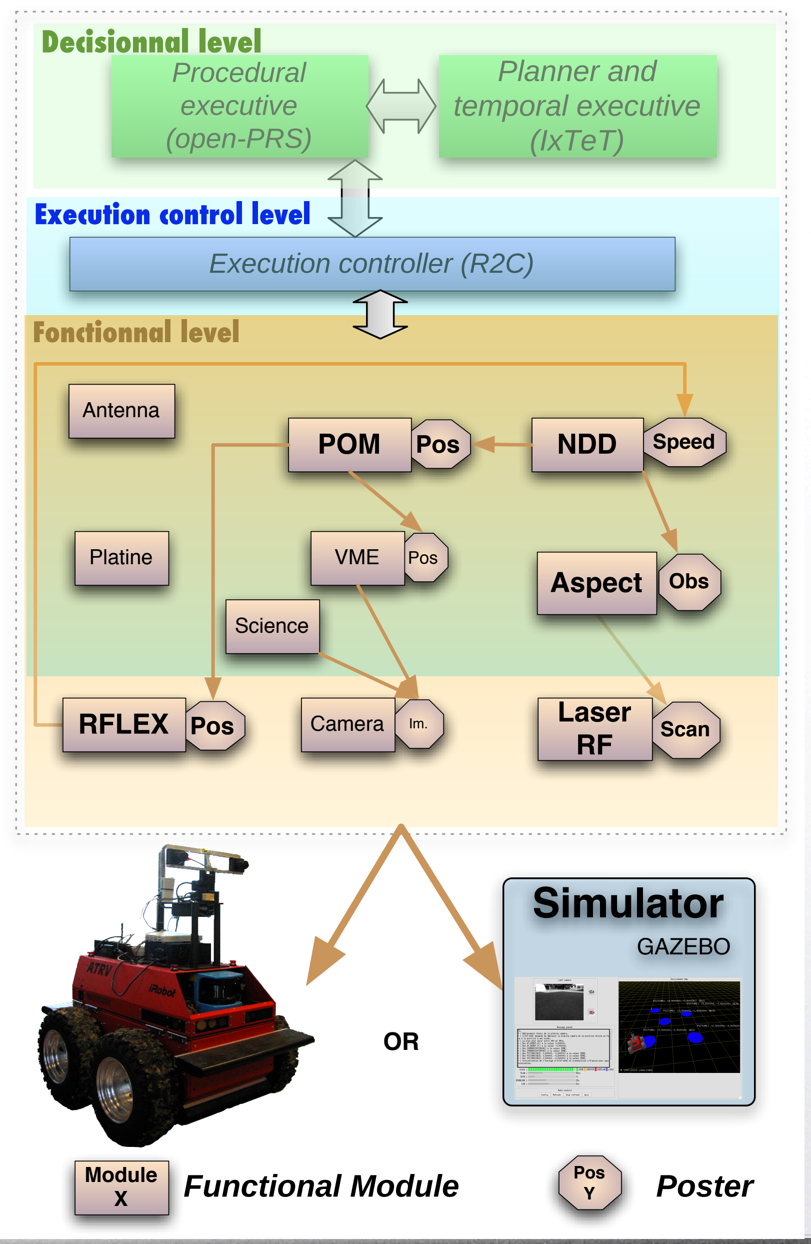


Ongoing work

- Time property:

  Laser scans an obstacle at *t*, which enters the loop (Aspect, NDD, RFLEX) and induces a stop (or avoidance) of the robot at *t*'.

  What's the delay ($|t'-t|_{max}$) we can guarantee?



Current Limitations/Prospectives

- Philosophical :
  - complexity of verification techniques for the whole architecture?

    state-space exploration, tick-based representation

  - integration of the executive as a BIP component?
    - by acquiring macro actions? (*Move*, *TakePicture*...)
    - by acquiring the complete plan?

      In this case, what about plan verification?

- Recherche PostDoc sur ce sujet...