Structuring processes into abilities : an information-oriented architecture for autonomous robots

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1 Context

2 Our proposal

3 Conclusion and future work

Presentation Plan

1 Context

2 Our proposal

3 Conclusion and future work

Work context

- The PEA project ACTION http://action.onera.fr

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- In particular, controlling an UGV:

Work context

- The PEA project ACTION http://action.onera.fr
- In particular, controlling an UGV:
- Common tasks :
  - Exploring
  - Tracking target
  - Following target

Problem statement

Considering

- a set of robot capacities
- a (set of) mission(s)
- a more or less unknown environment

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- a set of robot capacities
- a (set of) mission(s)
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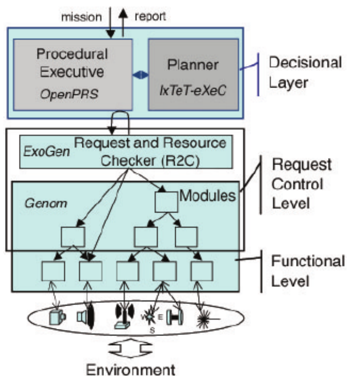
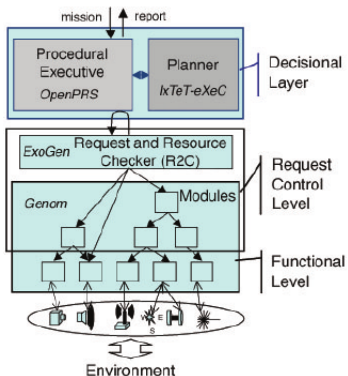
How to organize this different processes to achieve the mission ?

- in an efficient way
- in the most autonomous way

Related work : 3-layer architecture



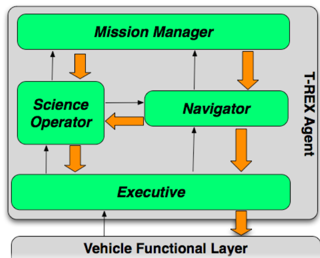
Related work : 3-layer architecture



Issues with this approach

- Different representation between layers ⇒ difficult diagnostic
- Scalability issues
- Monolithic blocks

Related work : 2-layer architecture



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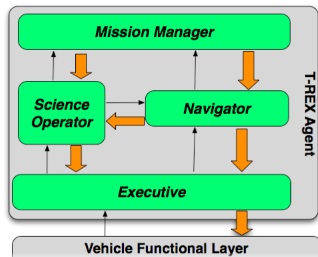
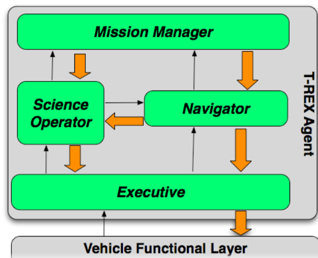


Improvements

- Better interaction in decision layer
- Problem partition $\Rightarrow$ better reactivity

Related work : 2-layer architecture



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- Problem partition $\Rightarrow$ better reactivity

Issues

- non-composable decomposition

Requirements

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What is an information ?

- robot internal state
- possible futures of the robot (i.e. plan)
- data from the outside world, processed or not.

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- possible futures of the robot (i.e. plan)
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Why partitioning on top of information ?

- Information is a first-class object of the functional layer
- Competition on information acquisition
- Information is robot-agnostic

Ability notion

Definition

- Each piece of information is encapsulated in an *ability*
- This information can be constrained by some free variables

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A more formal definition

$$Ability = < N_a, S_r, S_w, S_i, S_T, S_F, S_{Ta}, S_{rt} >$$

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Identifier

- N_a : ability identifier

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Context

- S_r : Readable variables, real information
- S_w : Writable variables, control ability behaviour
- S_i : Internal variables

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Programmation environment

- S_T : a set of types
- S_F : a set of functions, which works on previously defined S_T

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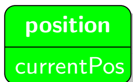
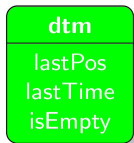
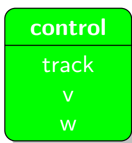
Tasks

- S_{Ta} : a set of tasks
- S_{rt} : a set of relation between tasks

Abilities network







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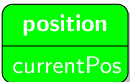
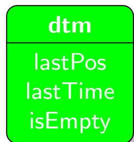
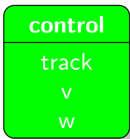




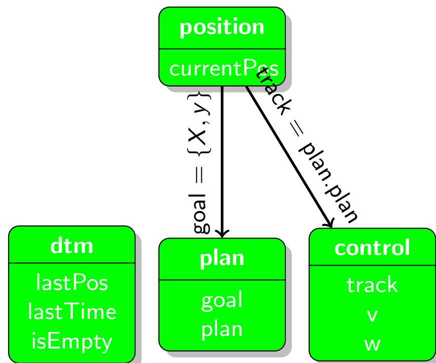


Run-time support

- Nameserver function
- Gives the list of running abilities
- Monitors the status of each ability

runtime

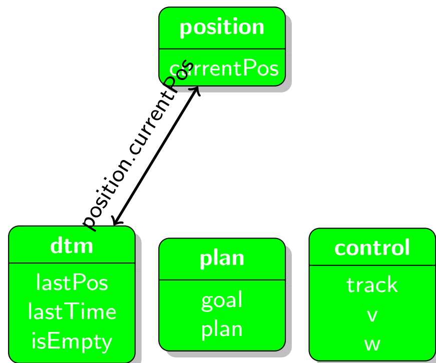
Abilities network



Control flow

- Asynchronous protocol
- Ends with
  - OK message
  - FAILURE message
  - KILLED message

Abilities network



Data flow

1. Fed using an asynchronous request / reply
2. Future update uses a publisher / subscriber interface

Tasks and recipes

Tasks

- Define how to pass from a symbolic state to another one
- Mainly defined by their pre and post-condition

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Tasks and recipes

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Recipes

- Implement different strategies for one task
  - Recover from local error
  - Use different strategies for the same task

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Pre / Post-condition description

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- Boole logic formula of clauses
- Clauses are comparison or function application on variables and constants

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```
        * (size < 42)
        * (pos::distance(pos::curentPosition, planning::goal) < threshold)
```

Recipe definition

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- **make** < constraint > : constrain a remote ability (one-shot)
- **ensure** < constraint > : constraint a remote ability (continuous)
- **wait** < condition > : wait until the condition is true
- classical loop and branch mechanisms

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```
3DPath_handle_failure = recipe {
        Pre = {{ 3DPathFailure == true }}
        Body = {
        /* Get some new information */
        make ( pos::computeDistance(Dtm::lastMerged, pos::currentPostion) == 0.0))
        /* Restart the classic processing */
        ensure ( pos::computeDistance(Dtm::lastMerged, Pos::currentPosition) < threshold)
                 && 3DPath::goal == currentGoal
                 && Control::tracker == 3DPath::plan)
        wait(pos::computeDistance(goal, Pos::currentPosition) < goalThreshold))
        }
}
```

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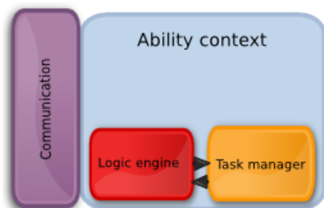
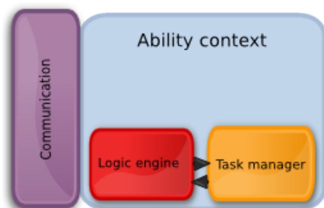
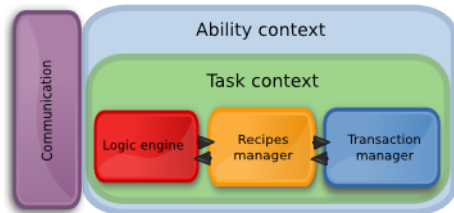
Overview of ability and task implementation



Overview of ability and task implementation





Logic engine

Goal

Find a set of tasks to achieve new constraints

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When

- When receiving new constraints from outside
- to recover from a task failure

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1. Rules selection on variable type

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Find a set of tasks to achieve new constraints

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How

1. Rules selection on variable type
2. Classical unification / rules selection / backtracking
3. Heuristic used on the base of:
   - number of pre-condition not fulfilled
   - number of tasks involved
   - number of tasks "not runnable"

Transaction manager

Goal

1. Handle lazily complex constraints
2. Handle switch between recipes

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Handling complex constraints

- Register each constraints
- When receiving part of answer, reduce the global expression
- Terminate when expression is reduced to true or false

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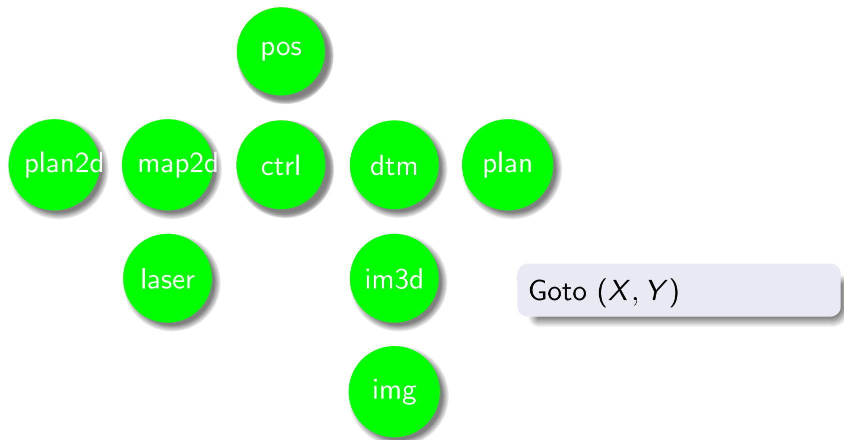
Recipes switch

- Recipes classification
- Cleaning task context or handling it transparently ?

Illustration



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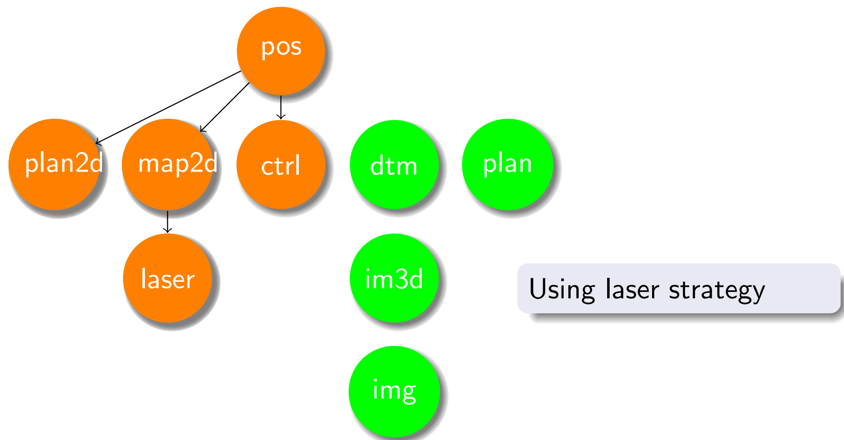

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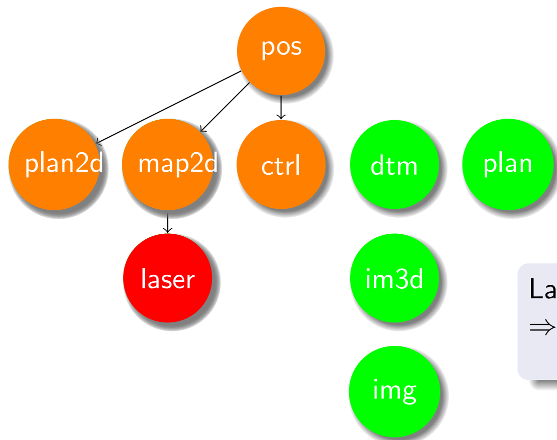
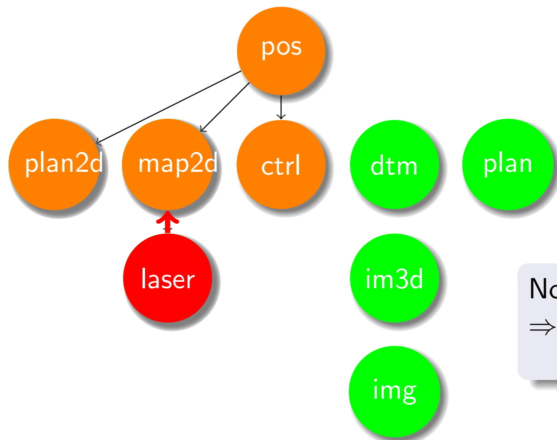


Laser fails
⇒ another recipe ?

Illustration



No other recipe
⇒ Another task set ?

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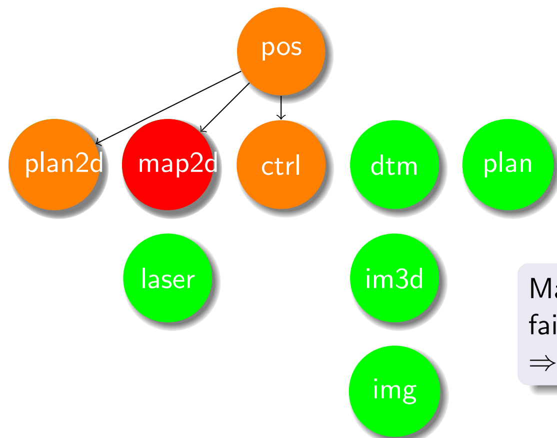

Map2d fails due to laser failure
$\Rightarrow$ another recipe ?

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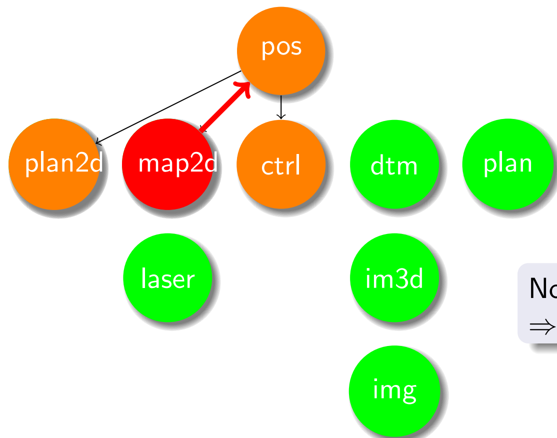

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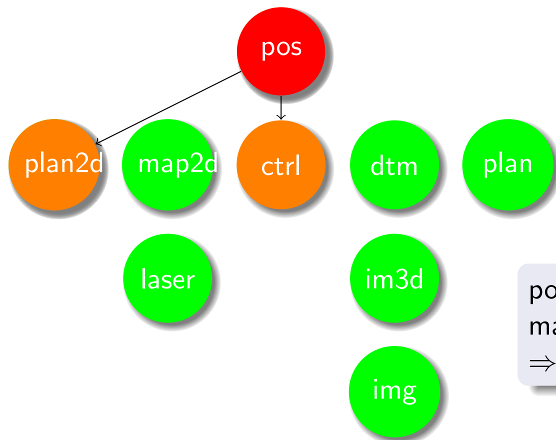

position fails due to map2d failure
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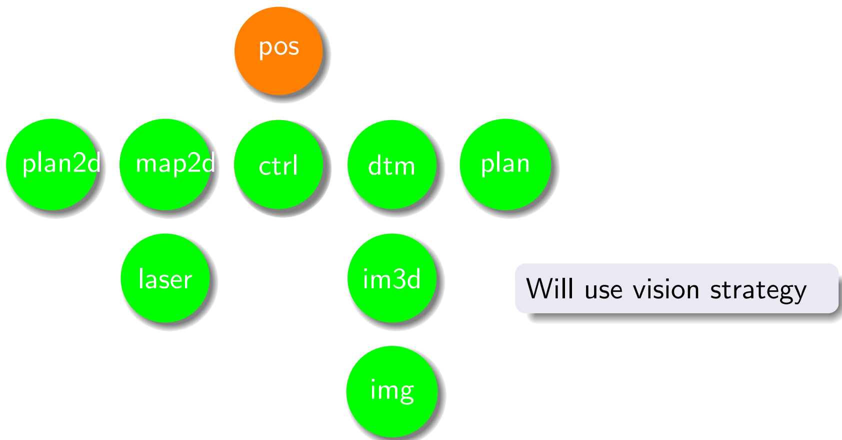

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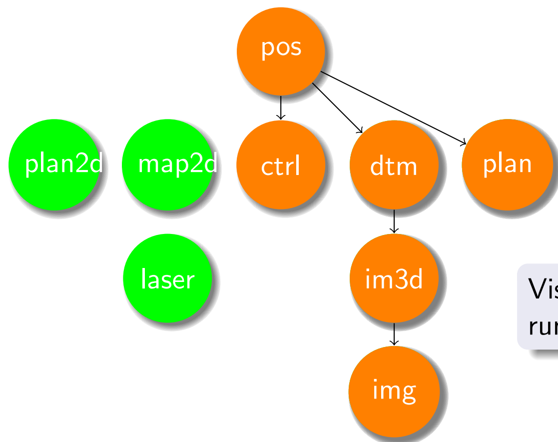

Vision strategy is running

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Conclusion

Requirements

- Reactive to external event, "adaptable" :
  - logic engine

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- Generic, modular, extensible :
  - Decomposition on information, decomposition on different layer

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- Reactive to external event, "adaptable" :
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- Robust to single component failure :
  - Separate process, run-time support
- Generic, modular, extensible :
  - Decomposition on information, decomposition on different layer
- Verifiable, "provable"
  - To Be Done :D

Inspiration

Various programming languages

- Erlang (concurrency)
- Datalog / Prolog (logic)
- Oz / Mozart, Alice (functional / concurrent / logic)

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Processes algebras

- CSP (Communicating Sequential Process)
- CCP (Concurrent Constraint Programming)
- TCCP and UTCCP (Temporal Concurrent Constraint Programming)

Future work

- Implement completely the proposed solution, and test it on a real robot

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- Improve the formalism : make some link with classic processes algebra like CSP, CCP or more recently UTCC
- Enhance the framework to deal with multi-robot problematic