


ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

www.onera.fr



An Orocos-based decisional architecture for the Ressac missions

Guillaume Infantes, Charles Lesire, Henry de Plinval,
and Florent Teichtel-Königsbuch

CAR'09, 23/04/2009

ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

The Ressac missions

Two Yamaha Rmax Autonomous helicopters for typical missions :

- ▶ Search and Rescue
- ▶ Natural hazard monitoring
- ▶ Cooperative exploration and tracking



The Ressac missions

Search and Rescue

1. Fly over a search zone and take pictures ;
2. Map the zone to find landable subzones ;
3. Plan a rescue policy from this mapping ;
4. Follow the policy (go to a subzone, remap, land or go to another subzone) until the mission is done or aborted.

Ressac onboard architecture

Orocos and Ressac components

Supervision

Planning

Conclusion

Ressac onboard architecture

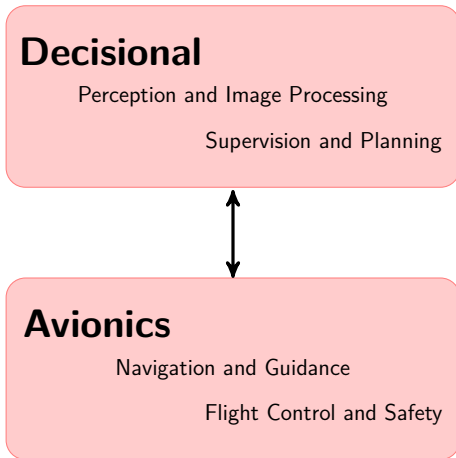
Orocos and Ressac components

Supervision

Planning

Conclusion

The Ressac architecture



The Ressac architecture

Avionics sensors

- ▶ Differential GPS : Novatel receiver + Egnoss satellites + RTK DGPS ;
 - ▶ Inertias (native Yamaha helicopters') ;
 - ▶ Magnometers (HMR 3000) ;
 - ▶ Laser range finder for altitude measurements (Dimetrix) ;
 - ▶ Pressure sensors for altitude measurements ;
- Hybridation by standard [Kalman filtering](#).

The Ressac architecture

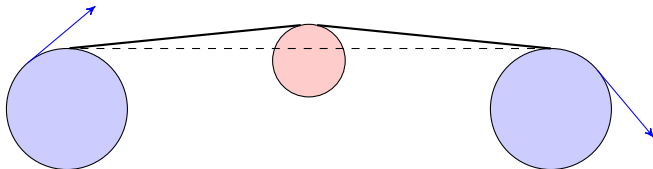
Piloting

- ▶ Standard PID controller designed and tuned for every channel around equilibrium conditions ;
- ▶ Safety management ensuring reactivity and efficiency in risk management.

The Ressac architecture

Guidance

- ▶ SNAKE (Système de Navigation Autorisant une Kyrielle d'Évitements)
- ▶ 2D minimum time trajectory from given pose to desired pose, with maximum rotational speed constraint ;
- ▶ real-time geometrical solution by drawing initial and final circles of maximum rotational speed.



The Ressac architecture



- ▶ Camera AVT Marlin
 - ▶ F145 B2 (black and white)
 - ▶ F145 C2 (color)
- ▶ 58mm × 44mm × 29 mm ; 120 g.
- ▶ Firewire (IEEE 1394a)
- ▶ Up to 10 fps
- ▶ Up to 1392 × 1040

Ressac onboard architecture

Orocos and Ressac components

Supervision

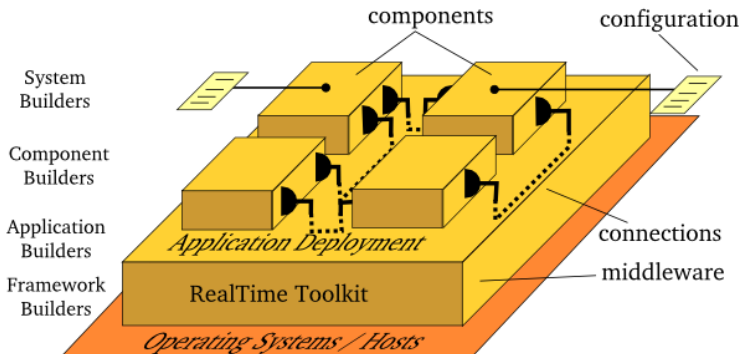
Planning

Conclusion

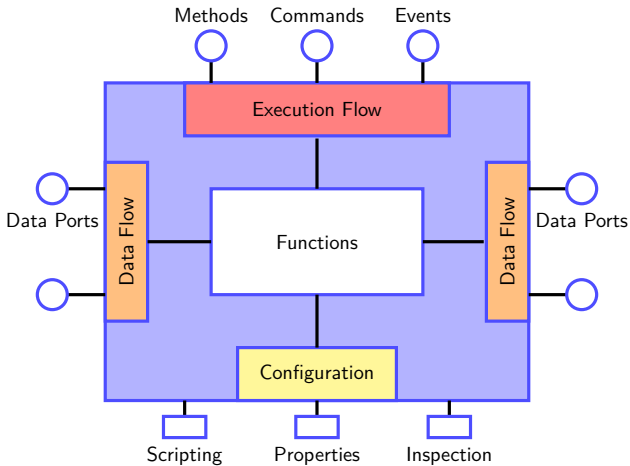
Orocos

- ▶ Open RObot COntrol Software (www.oroocos.org)
- ▶ Open-source project from Leuven University (Belgium)
- ▶ 4 libraries :
 - ▶ Real-Time Toolkit (RTT) : all for development and execution
 - ▶ Orocos Component Library (OCL) : some useful components
 - ▶ Bayesian Filtering Library (BFL)
 - ▶ Kinematics and Dynamics Library (KDL)

Orocos



Orocos Components



Ressac
○○○○○○○○

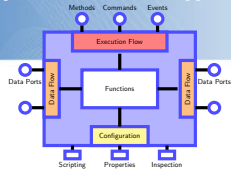
Orocos
○○●○○○○○○

Supervision
○○○○○

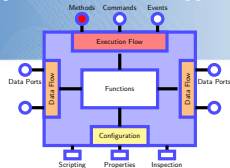
Planning
○○○○

Conclusion
○○

Orocos Components



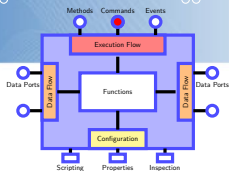
Orocos Components



Method

Function called *synchronously*, i.e. executed by the caller's thread.

Orocos Components



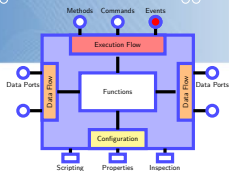
Method

Function called *synchronously*, i.e. executed by the caller's thread.

Command

Function called *asynchronously*, i.e. sent by the caller and executed by the owner.

Orocos Components



Method

Function called **synchronously**, i.e. executed by the caller's thread.

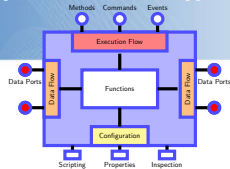
Command

Function called **asynchronously**, i.e. sent by the caller and executed by the owner.

Event

Events are emitted, i.e. **published** to subscribers. Subscribe can bind synchronous or asynchronous functions to events.

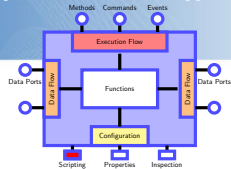
Orocos Components



Data

- ▶ Shared objects between components.
- ▶ Read/Write access.
- ▶ Whether buffered or not.

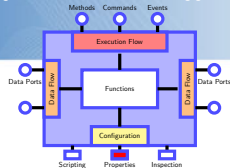
Orocos Components



Script

Programs or State Machines loaded as script files.

Orocos Components



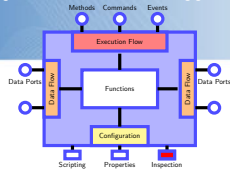
Script

Programs or State Machines loaded as script files.

Properties

Attributes loaded from xml configuration files.

Orocos Components



Script

Programs or State Machines loaded as script files.

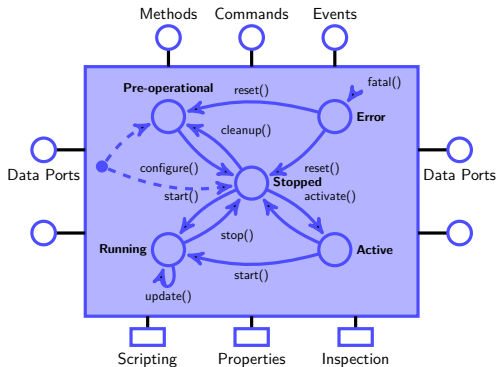
Properties

Attributes loaded from xml configuration files.

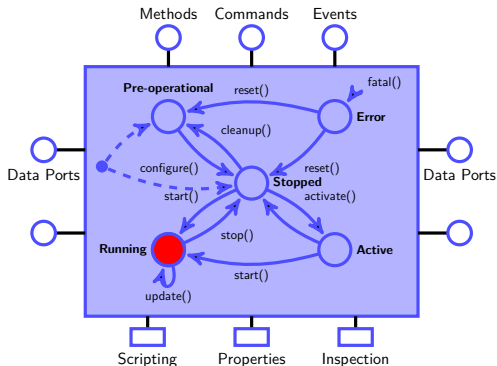
Logging

Link to a logger component to log information to output streams (cout, files, ...)

Orocos Components



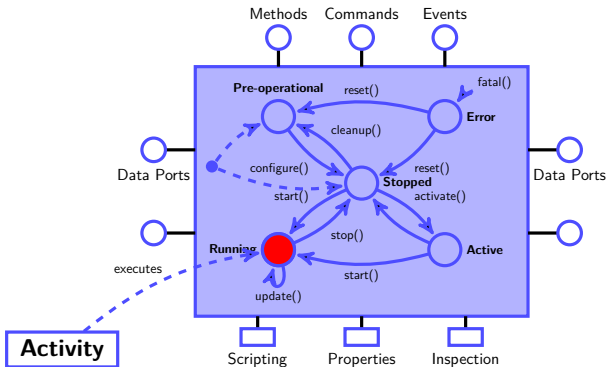
Orocos Components



While **Running** :

- ▶ handles pending **commands** and **events** ;
- ▶ executes program and state machine **scripts** ;
- ▶ executes internal **update** function.

Orocos Components



Activities :

- ▶ whether periodic or not ;
- ▶ same period activities scheduled using priorities ;
- ▶ may be manually, event- or data-triggered.

Orocos Components

Deploying components

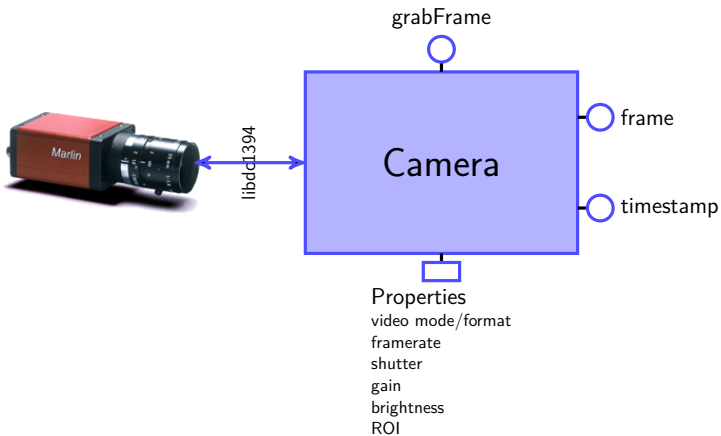
- ▶ Directly in C++
Using the C++ RTT API to connect data ports, load properties, set activities. . .
- ▶ Using the `DeploymentComponent` (OCL)
Loads a XML file at startup describing the components to load, their activities, their property file, the data links. . .

Ressac Components

Development of Orocos components for Ressac :

- ▶ Image acquisition from video camera,
- ▶ Image processing algorithms,
- ▶ Ressac state vector acquisition from the avionics computer,
- ▶ Ressac navigation requests sent to the avionics computer.

Ressac Components

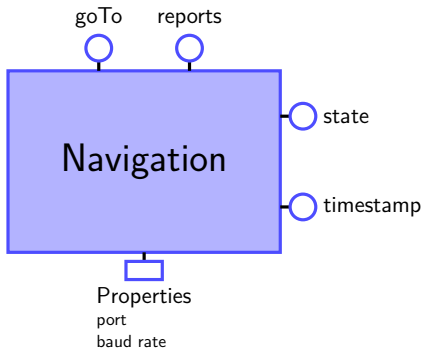


Ressac Components

Camera related components :

- ▶ **FirewireCamera** grabbing images from a firewire camera ;
 - ▶ **FileCamera** loading images from files (to replay an experiment) ;
 - ▶ **FrameReporting** saving images to files ;
 - ▶ **FrameDisplay** displaying images to an HMI.
-
- ▶ use OpenCV library

Ressac Components

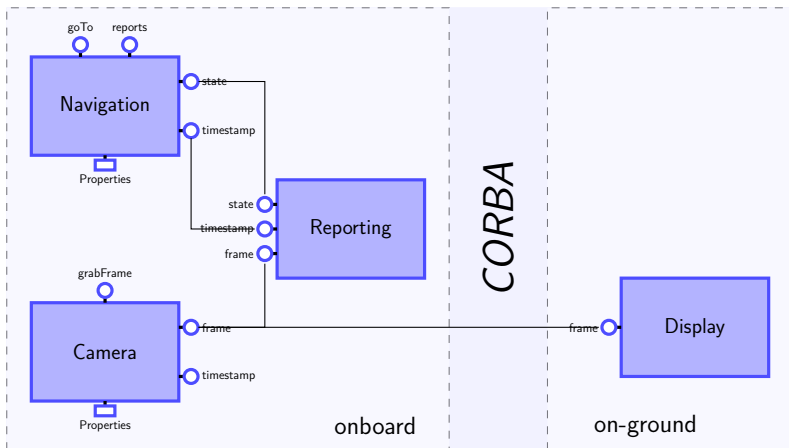


Navigation related components :

- ▶ **SerialNavigation** that connects to the avionics using a serial port ;
- ▶ **TCPNavigation** that connects to a simulated avionics using TCP/IP ;
- ▶ **FileNavigation** that loads state vectors from files ;
- ▶ **ReportingComponent (OCL)** that saves data to files.

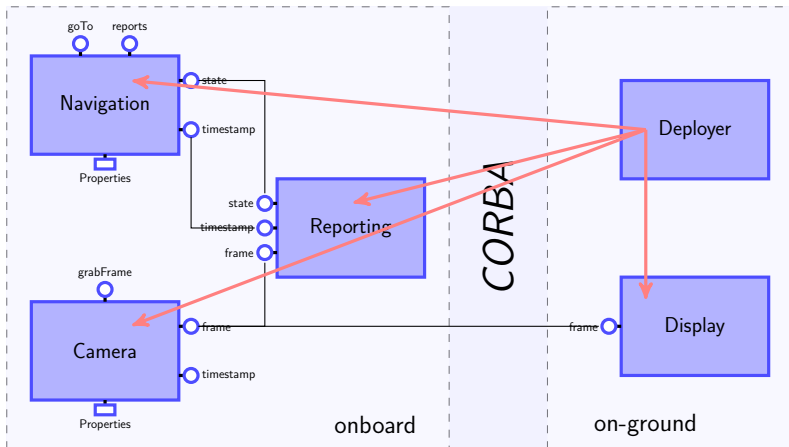
Ressac Components

Experimental setup for data acquisition :



Ressac Components

Experimental setup for data acquisition :



Ressac onboard architecture

Orocos and Ressac components

Supervision

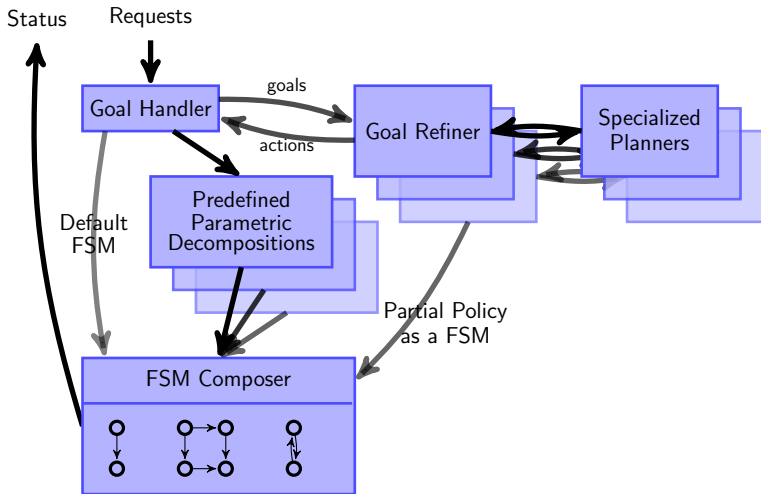
Planning

Conclusion

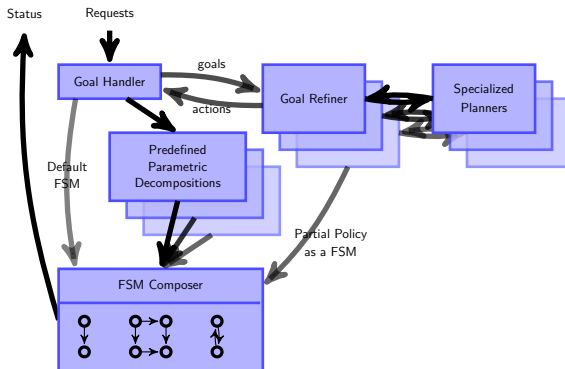
Supervision

- ▶ Handles goals arriving to the UAV (from outside, i.e. either an operator or other vehicles) ;
- ▶ Binds the goal to low-level state machines (camera, navigation), either :
 - ▶ directly (the goal corresponds to an elementary action),
 - ▶ using a known decomposition (a procedure to accomplish the goal), or
 - ▶ calling a planning process.

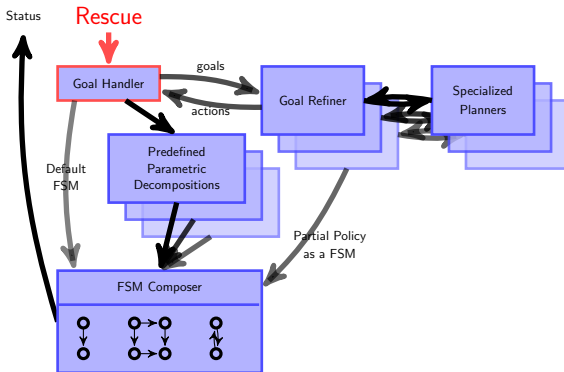
Supervision



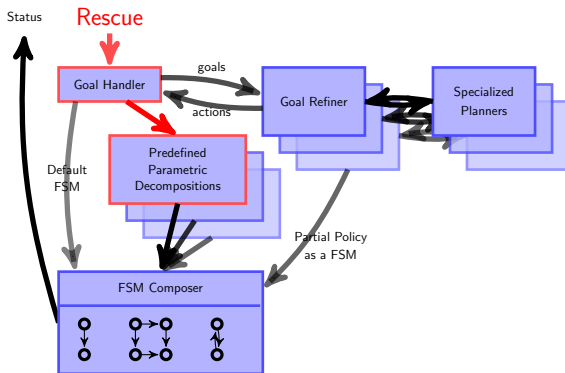
Supervision



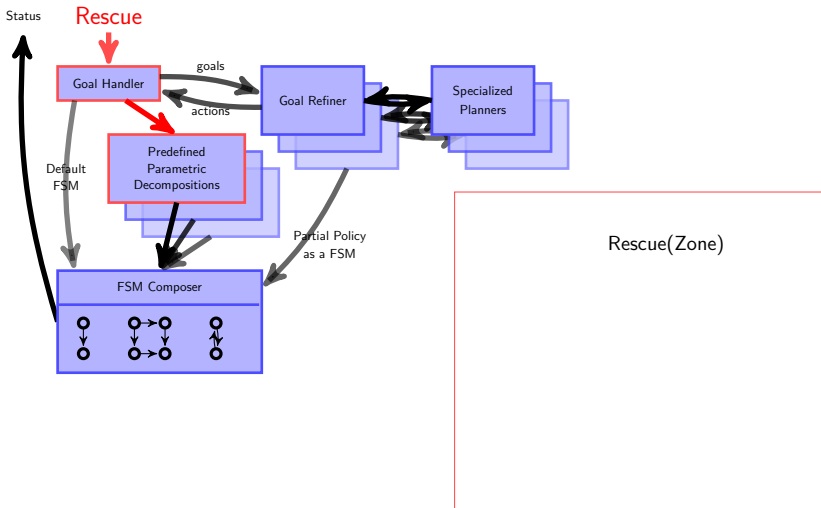
Supervision



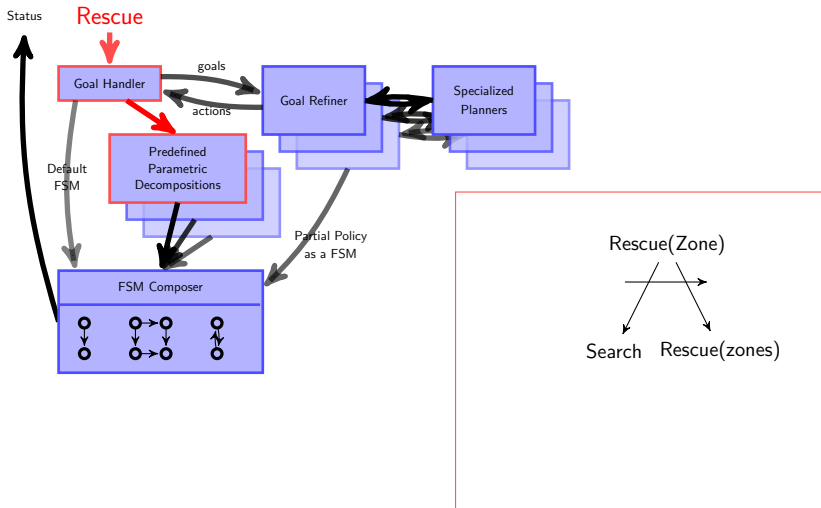
Supervision



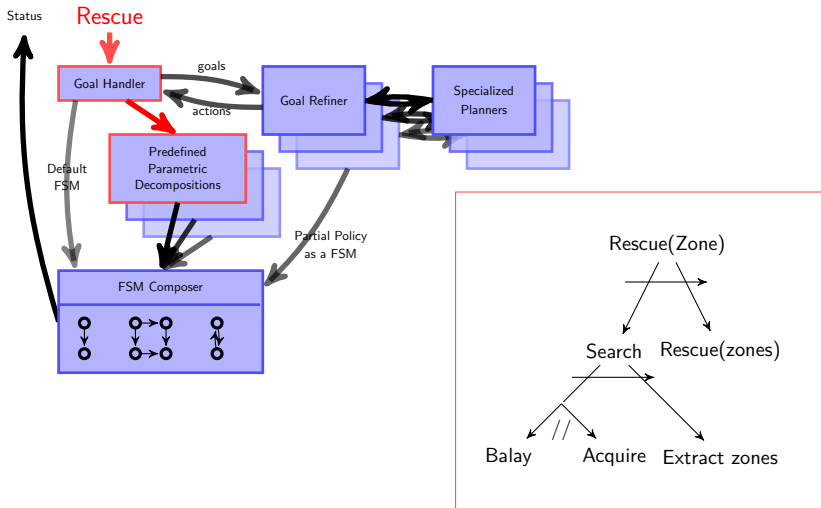
Supervision



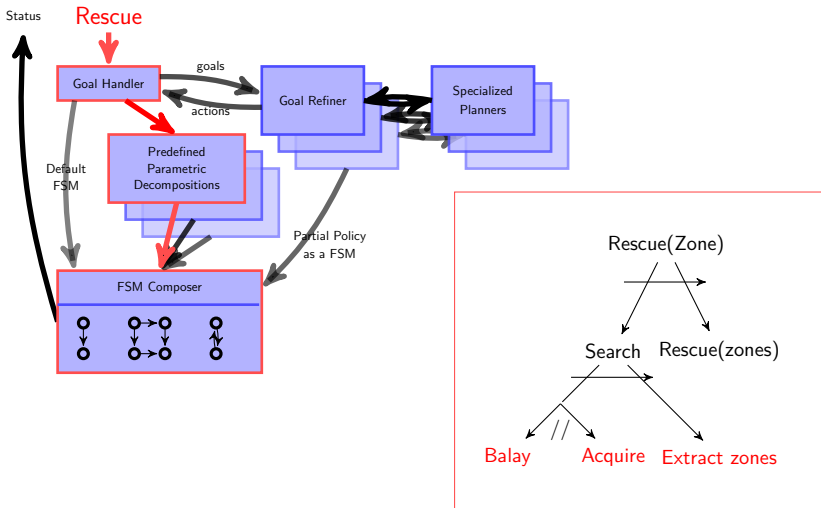
Supervision



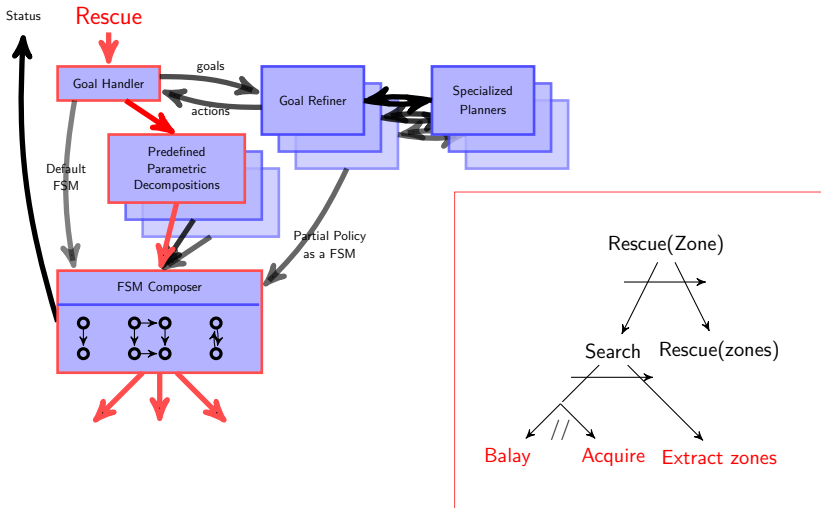
Supervision



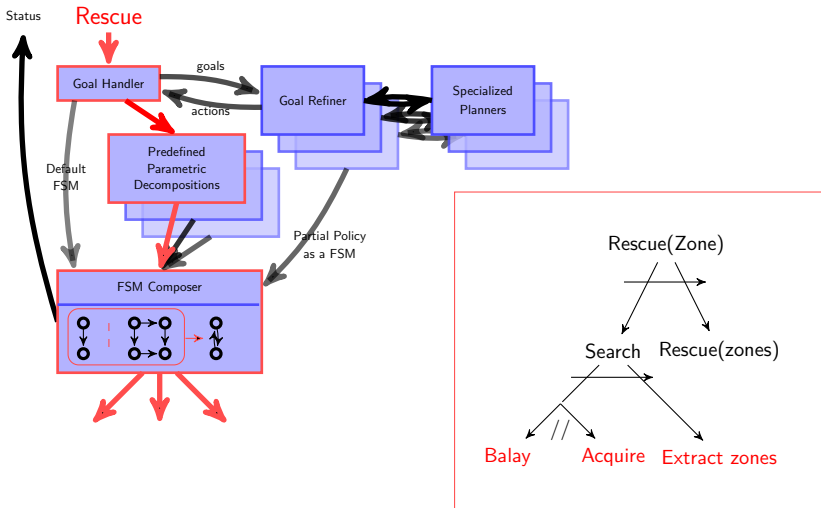
Supervision



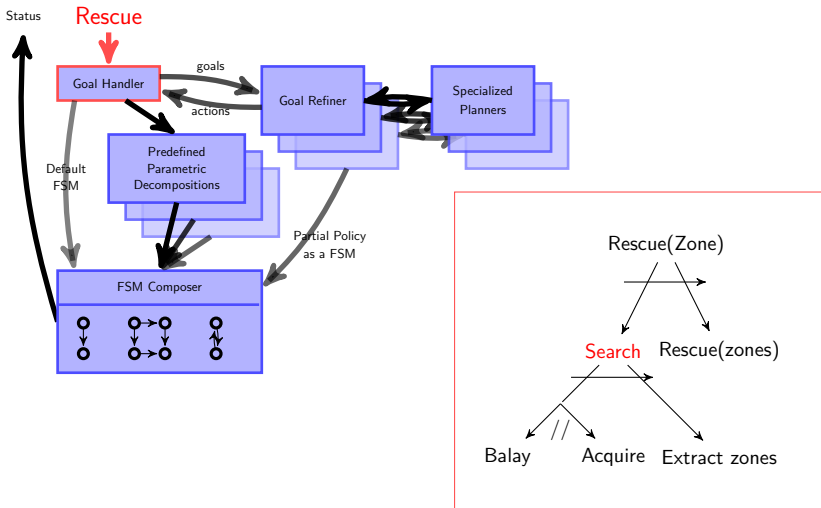
Supervision



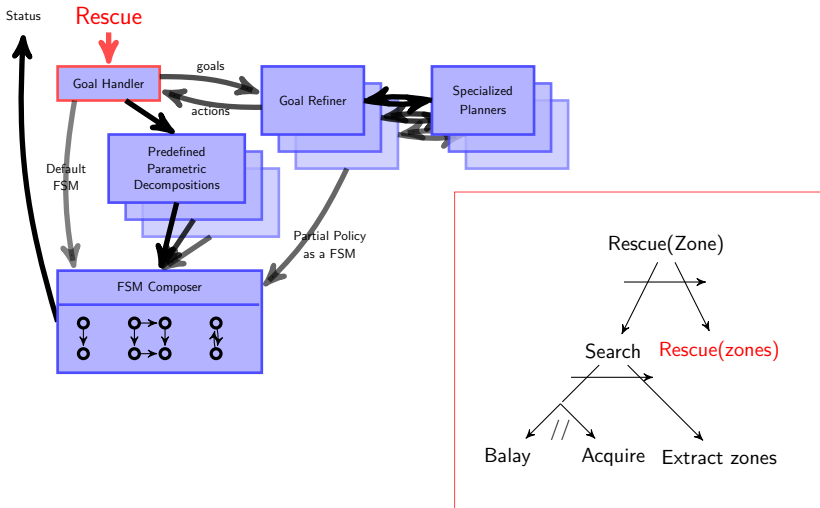
Supervision



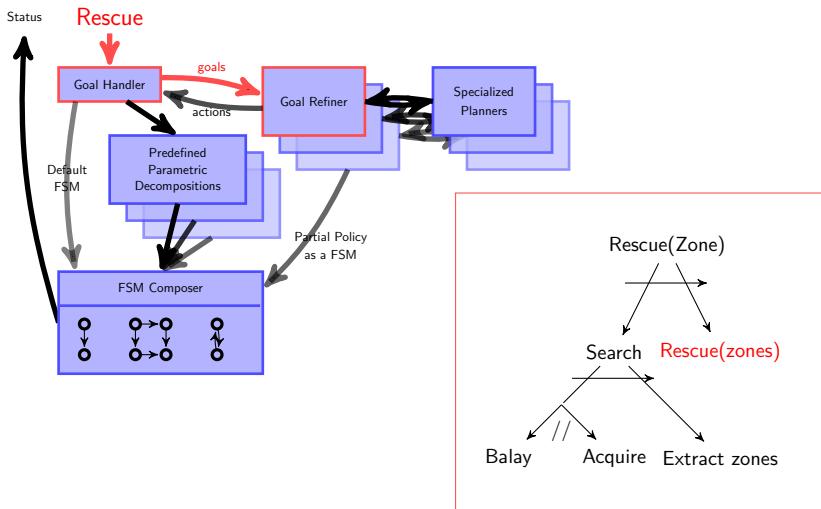
Supervision



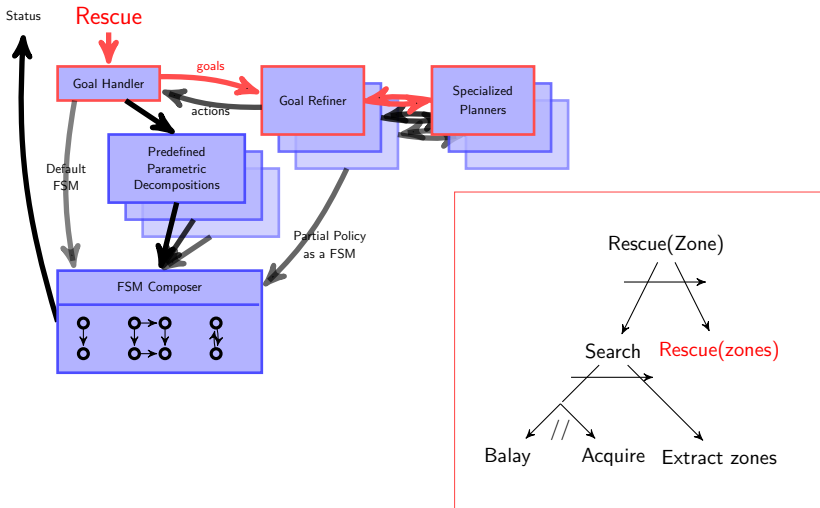
Supervision



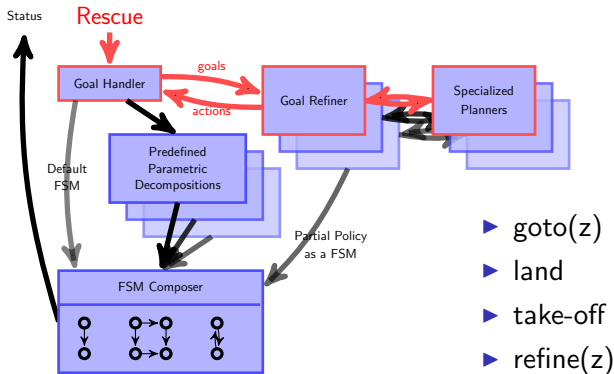
Supervision



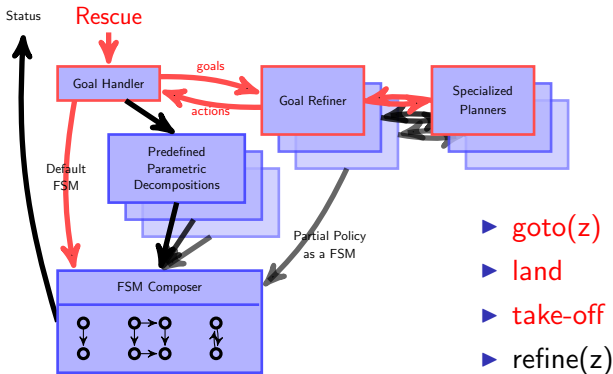
Supervision



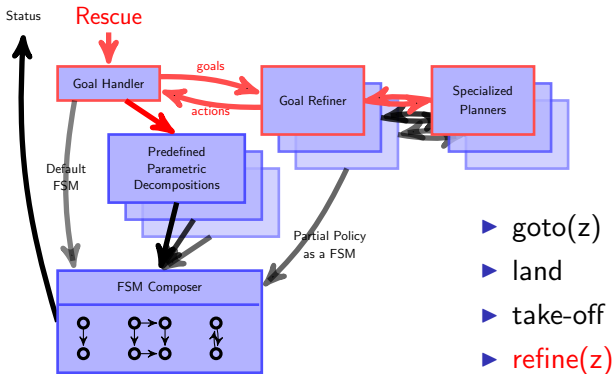
Supervision



Supervision



Supervision



Supervision

Supervision integration

- ▶ Goal Refiner as a Component interacting with planners ;
- ▶ Decomposition and Composer as a Component managing FSM ;
- ▶ Goal Handler :
 - ▶ as a Component ;
 - ▶ as a *Middleware*, implemented using Orocos events emission.

→ specification of interfaces between supervisor components...

Supervision

Verification

- ▶ Off-line verification of properties on available FSM and possible compositions,
- ▶ Or :
 - ▶ Encoding of safety constraints as FSM,
 - ▶ Permanent online composition of safety FSM
 - ▶ e.g., when fuel level low \Rightarrow goto base ;
 - ▶ Safety FSM must have priority !

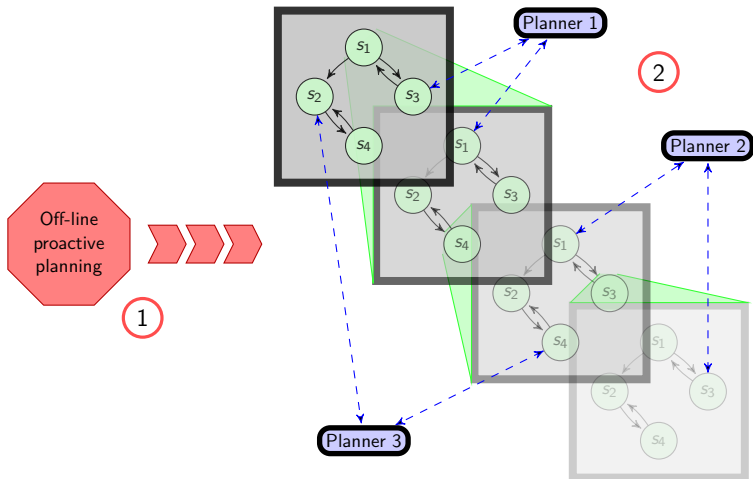
Ressac onboard architecture

Orocos and Ressac components

Supervision

Planning

Conclusion



Planning

1. Proactive planning

- ▶ Off-line generation of a robust plan (or policy),
- ▶ On-line :
 - ▶ Embedded in a black-box planner (next slide),
 - ▶ Used as a goal decomposition (generation of hierarchical FSM)
 - ▶ e.g., decomposition of **Rescue** planned off-line, by choosing image processing algorithms based on expected computation time and efficiency.

Planning

2. On-line reactive planning

- ▶ Several available (specialized) planners,
- ▶ Planners are black-boxes that may return :
 - ▶ new goals, handled by the goal handler (decomposed to synchronized FSM)
 - ▶ e.g., Ressac **refine** action,
 - ▶ elementary actions, directly executed
 - ▶ e.g., Ressac **goto**, **land** actions,
 - ▶ a decomposition method, embedded in the supervisor.

Planning

Verification

- ▶ Off-line :
 - ▶ Verification of generated decompositions,
 - ▶ Verification of the plans envelope,
- ▶ On-line :
 - ▶ Verification of properties on the produced plan (or action),
 - ▶ When invalid – or not yet produced –, default plan available,
 - ▶ *Composition with Safety FSM.*

Ressac onboard architecture

Orocos and Ressac components

Supervision

Planning

Conclusion

Conclusion

- ▶ Functional components developed and integrated using Orocos ;
- ▶ Off-line generation of supervisor decompositions ;
- ▶ Supervisor handling and decomposing goals, while ensuring safety behaviors ;
- ▶ Possibly calling planners to refine/decompose some actions.

Current works

- ▶ Vision-related components tested in flight ;
- ▶ Navigation-related components in test at lab ;
- ▶ Supervision and planning components in development ;
- ▶ Experiments planned during summer.