VERTEILTE SYSTEME

Reliable Robotics – Diagnostics++

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RoboCup

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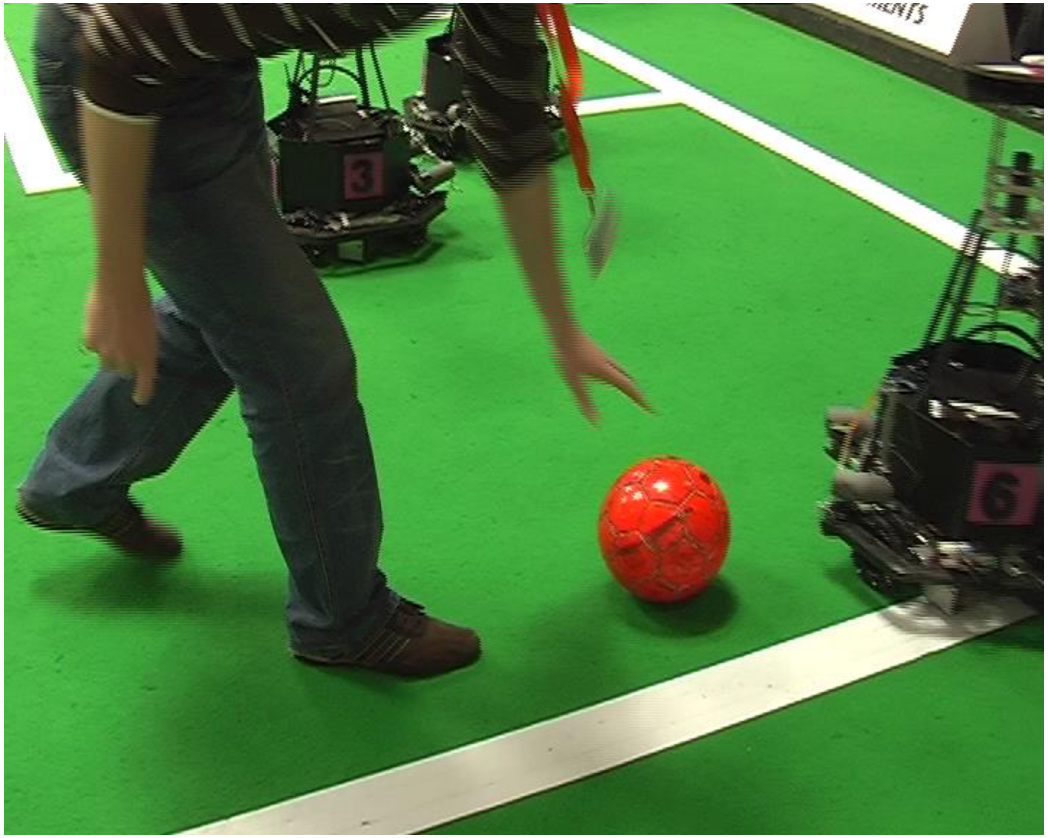
Story board

- Motivation
- Introduction to ROS diagnostics
- **ROS diagnostics extensions**
- Takeaways

Robot Failures are facts …



Robot Failures are facts …

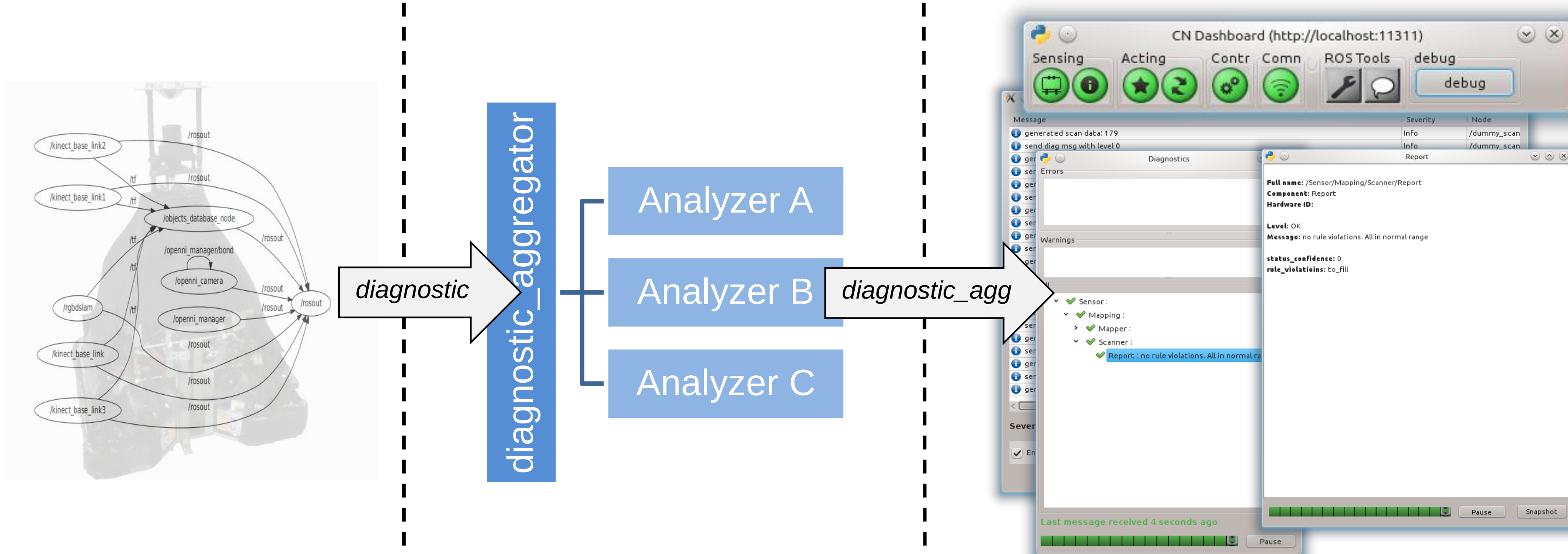
But what to do about it?

What can we do about it?

- We have to correct the problems or avoid the failure.
- **Problem:** You need to know the root cause before you can correct the problem
- **Situation** (without a diagnostic support)**:**
  - Limited to visible observations
  - Limited to developer experiences
- **Approach** (with ROS diagnostics)**:**
  - Reduce subjective assessment
  - provide objective data of the state of the system
  - Filter the data to extract the problem
  - Notify the operator

How ROS diagnostics fits in – A short Overview

Monitoring | Aggregation/Diagnosis | Presentation



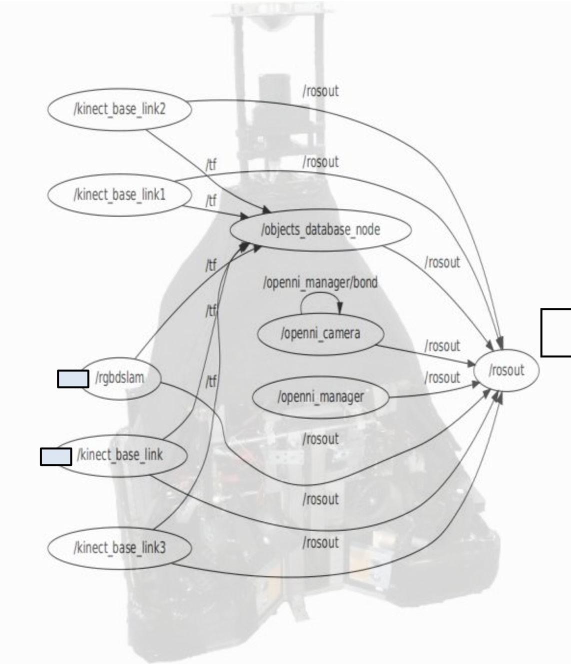
- *diagnostic_updater*
- *self_test*

- *diagnostic_aggregator*

- *rxconsole*
- *robot_monitor*
- *PR2_dashboard*

How to provide current status data?

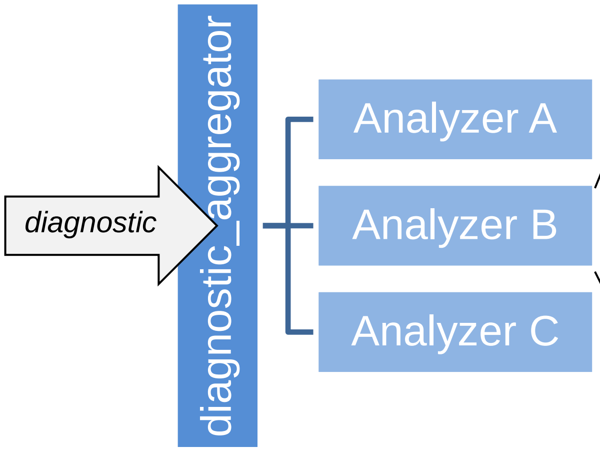
```
void callback (DiagnosticStatusWrapper &stat) {
   stat.summary(DiagnosticStatus::WARN,
        "This is a silly updater.");

   stat.add("Stupidicity of this updater", 1000.);
}

int main(int argc, char **argv) {
   // ... some node specific stuff
   // create updater
   diagnostic_updater::Updater updater;
   // name updater
   updater.setHardwareIDf("Device-%i-%i", 27, 46);
   // add a call back to the updater
   updater.add("Function updater", callback);

   while (nh.ok()) {
      // ... some node specific stuff
      pub1.publish(msg);

      updater.update();
   }
}
```




```
# This message holds the status of
# an individual component of the robot.
#

# Possible levels of operations
byte OK=0
byte WARN=1
byte ERROR=2

# level of operation enumerated above
byte level

# a description of the test/component
# reporting
string name

# a description of the status
string message

# a hardware unique string
string hardware_id

# an array of values associated with
the status
KeyValue[] values
```

- *diagnostic_updater* provides run-time data for the node‘s state
- Supports to embed this code in the node
- Unified interface (topic *diagnostics*, weakly typed message fields)

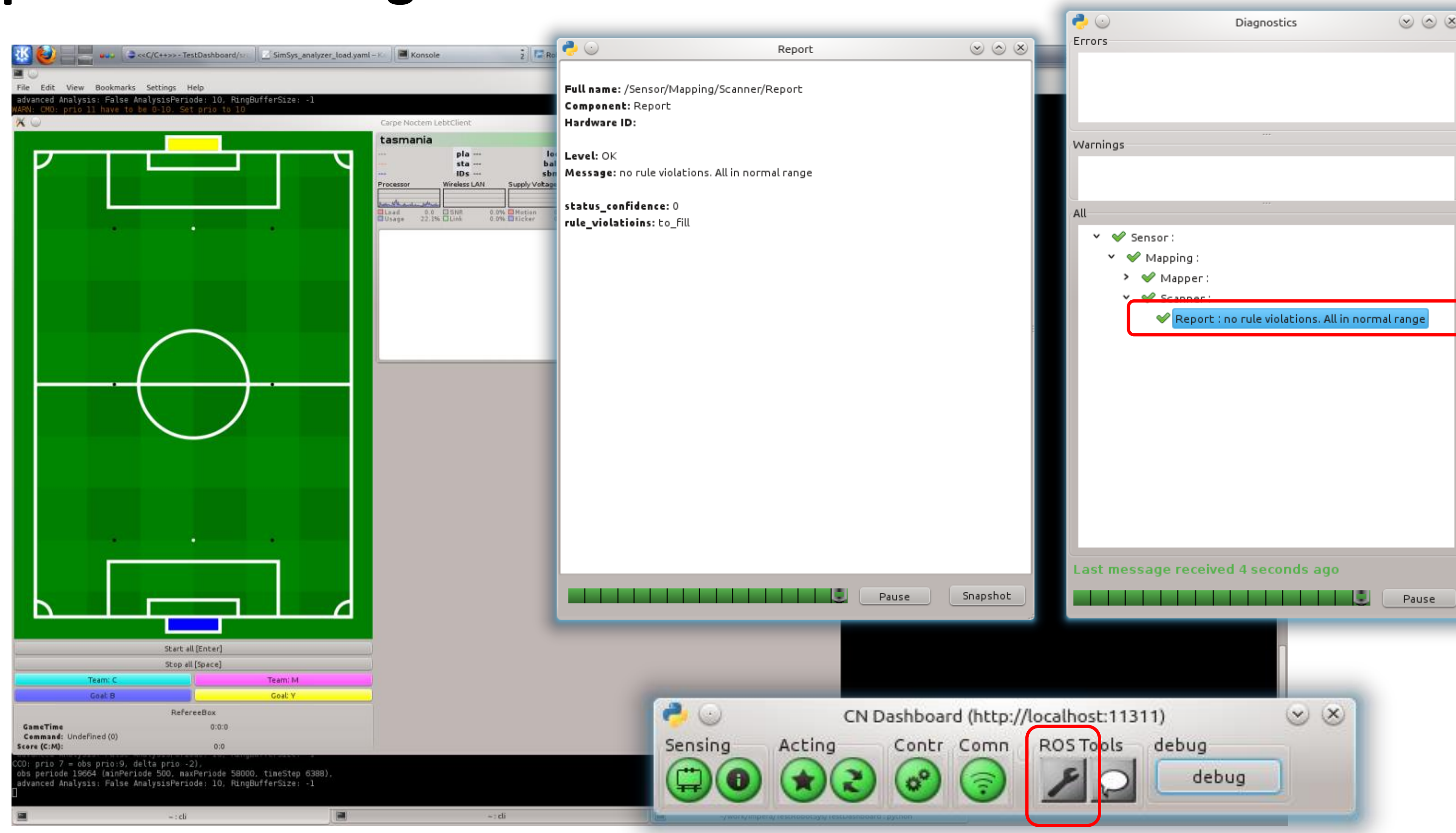
How to diagnose a problem?




```
bool ArmControl::match(const std::string name) {
  if (name == this->nodeToAnalyze) return true;
 return false;
}

bool ArmControl::analyze(const boost::shared_ptr<StatusItem> item) {
  if (item->getName() == this->nodeToAnalyze) {
    if (item->hasKey("internal_state_val")) {
       l = boost::lexical_cast<int>(item->getValue("internal_state_val"));

       //decision rules ...
       if (l > 5)  this->ruleViolation[0] = 1;

    } else ROS_INFO("internal_state_val not in msg");
    return true;
  }
  return false;
}

vector<boost::shared_ptr<DiagnosticStatus> > ArmControl::report() {
  vector<boost::shared_ptr<DiagnosticStatus> > output;

  /* create and fill the DiagnosticStatus item ... */

output.push_back(ds);
  return output;
}
```

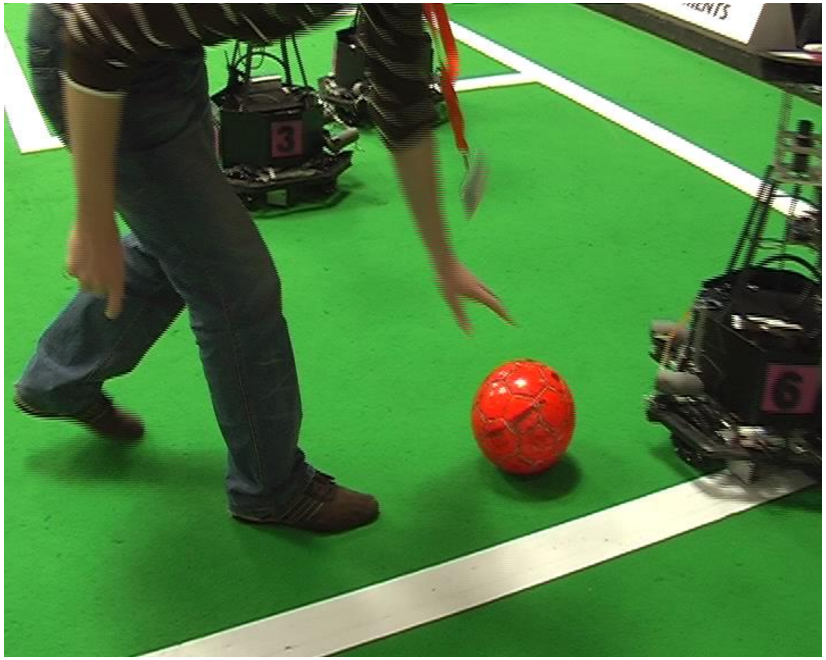
- Main purpose is to analyzes diagnostic data for presentation
- Configurable set of analyzers (plug-ins)
- Analyzers are useful for tasks like, grouping, suppressing invalid outputs, …

How to present the diagnostic results?



- Present the state of the system on a quick view
- Detailed information are accessable in a few steps

REP 107: Diagnostic System



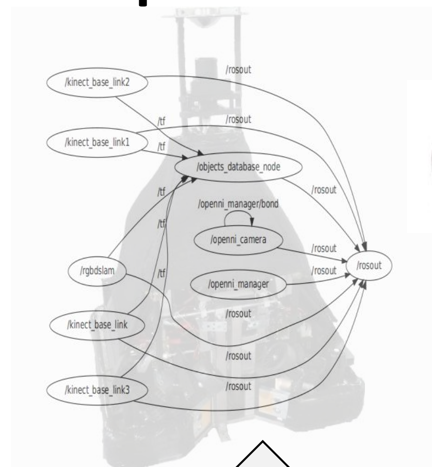
- ROS diagnostics is proposed:
  - to provide operator awareness,
  - to target hardware drivers only,
  - to have a default update interval (1Hz),
  - not to react to failures.
- The goal is operator awareness
  - Results to correct faults afterwards
- Diagnostics is targeted for hardware drivers only
  - “ … adding diagnostics to all software components creates too much noise …”
  - “ … the burden of logging and analyzing goes up significantly.”

Problem solved?

- … at least diagnostics is the right thing to start
- Limitations and shortcomings:
  - High integration efforts (hand-coded parts)
  - Limited diagnostic scope (software components)
  - No generic monitoring support (e.g. third-party modules)
  - Static update intervals
- For improvement we propose some extensions
  - **Generic monitoring** to extend the monitoring scope
  - **Model based integration support** to limit the hand coded parts
  - **Reactivity** to trigger fail-safe and repair functions

Generic Monitoring: How to extend the scope?

- **Robot = Software + Hardware**
- Hardware:
  - Driver nodes are limited to provided data
  - Some hardware provides diagnostic data
  - … but many do not
- General hardware diagnostic can not address application specific requirements
- Generic hardware diagnostic agent:
  - sense electrical values (voltage, current)
  - sense physical values (temperature, light, sound, …)
  - perform (simple) reactions

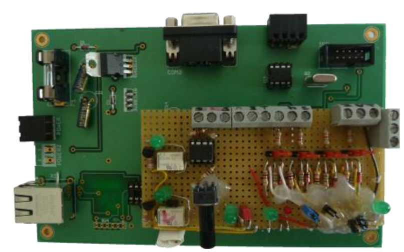


diagnostic

Sensors

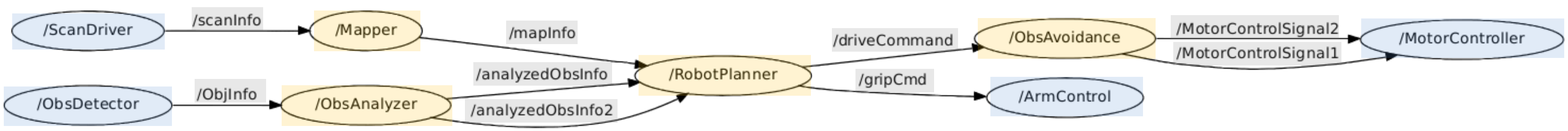
R232 CAN

ethernet



8 channels for measurement
Modular design (communication board + separat measurement board)

Generic Monitoring: How to extend the scope?

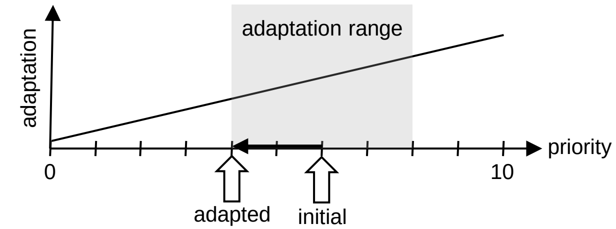


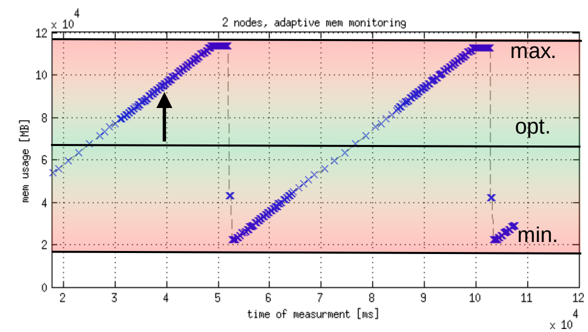
- Only driver nodes are proposed to be monitored (REP 107)
- But the system consists of further components
  - Non-driver ROS nodes
  - Third party nodes (e.g. nodes with libraries)
  - Communication links (e.g. depended failures [1])
- Extend the monitoring scope
  - Generic OS information for *black-box* nodes
  - Data flow monitoring of depended nodes
- Reduce the monitoring overhead

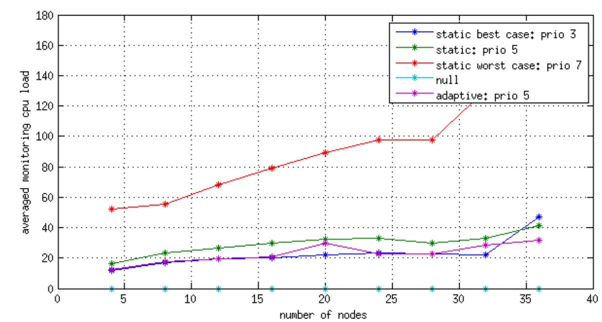
	Component	Flow
active	*diagnostic updater*	*diagnostic updater*
passive	OS data e.g. cpu, mem	communication data e.g. rate, value

Adaptive Monitoring: How to limit the overhead?

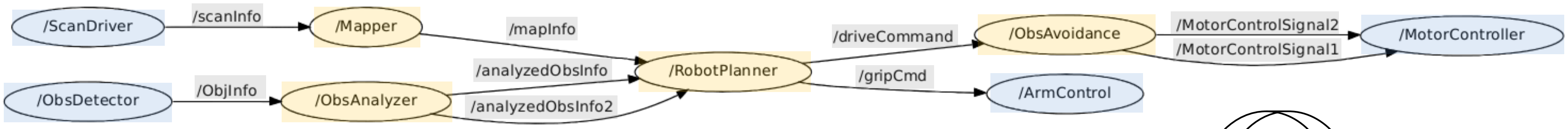
- Overhead increases with the extended scope
- **Individual priority levels** to control monitoring behavior for each node
- **Adaptation** of the monitoring
  - update rates, history length, mean, variance, …
  - Limited to a fixed range
- Properties
  - Types: minimum, maximum, range, histogram
  - Parameters: e.g. the optimal values
- Derivation metric defines the relative distance from the optimum
- Significant reduction of the overhead



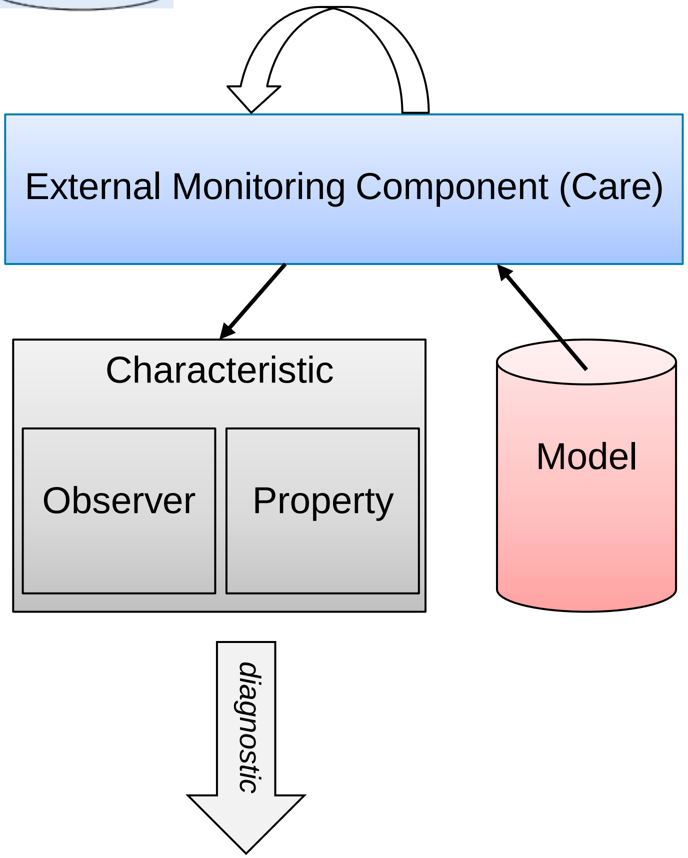




Generic Monitoring: How to realize the passive monitoring?

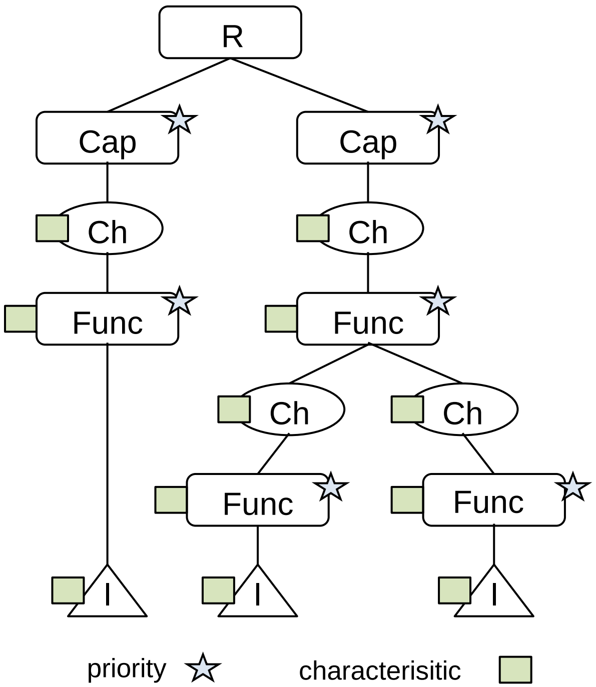


- External component for passive monitoring
- Poll generic process characteristics for *black-box* nodes
- Sniff communication for data flow analysis
- Design overview
  - Characteristics to manage the monitoring
  - Observer to poll the process information
  - Properties to specify expected values
  - Model to set up the needed characteristics



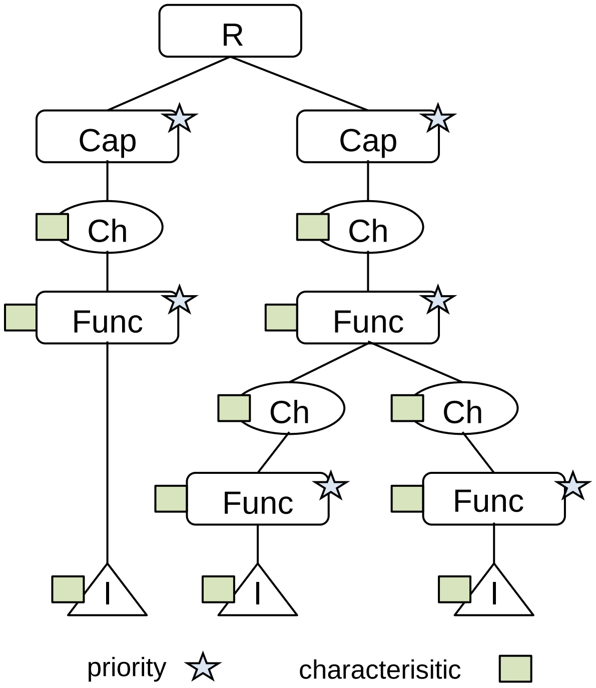
Integration Support

- ROS diagnostic relies on manual code and configuration parameters
- Generic monitoring introduced even more parameters
- Data flow monitoring needs an architectural model
- Central **robot model** to unify architectural information and configuration settings
- Tree presentation of the architectural composition
  - **Robot:** for global settings
  - **Capability:** a semantic grouping for a task relevant robot features
  - **Functionality:** a system node
  - **Channel:** a topic between system nodes



Integration Support: Robot Model

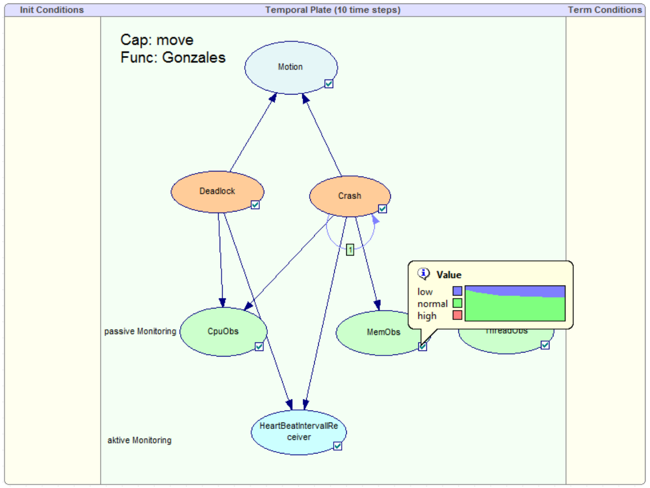
```
<?xml version="1.0" encoding="utf-8"?>

<robot name="tasmania" type="Gen10">

  <cap name= "grip" id="2" prio="5" used_in_role="WM09/WM09_Attacker:1">
    <chan name="GripControl" channel="gripCmd">
      <func name= "ArmControl" prio="2" working_dir="%ES_ROOT%/ArmControl/bin"
             filename= "ArmControl" arguments="">

        <charac name="cpuLoad" type="CpuLoad"
             proptype="Range" minvalue="0" maxvalue="200" ></charac>
        <charac name="memUsage" type="MemUsage"
             proptype="Range" minvalue="7000" maxvalue="7500"></charac>
        <charac type="ThreadUsage"
             proptype="Range" minvalue="4" maxvalue="10"></charac>

      </func>
    </chan>
  </cap>
...
</robot>
```



- Intuitive prioritization through hierarchical model structure
- Arbitrary configuration blocks, like a generic monitoring configuration
- XML description as proof of concept

Integration Support: soft diagnosis

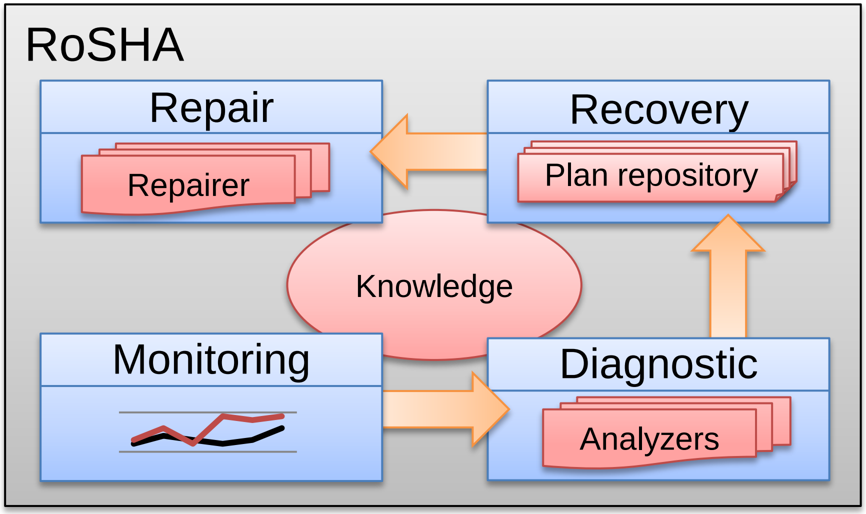
- Application specific hand-coded rules in the analyzers
- But often we do not know exactly these rules
  - Uncertainty
  - Lack of knowledge
- Reduce the burden of expert knowledge by methods of Soft Computing (Bayesian Networks)
- Dynamic Bayesian Networks to introduce temporal behavior
- Graphical modeling support through the SMILE/GENIE framework [2]



GENIE: Graphical Frontend for modeling Bayesian Networks [2]

Autonomous Reactions: An Outlook

- Complement operator awareness with autonomous reactions
- MAPE-K cycle as the decision cycle
- Work in progress:
  - Generic monitoring
  - Diagnostic: Analyzers using soft diagnosis
  - Knowledge: robot model to ease the integration and configuration
- Future work:
  - Recovery planning based an diagnostic results
  - Repair execution



RoSHA: A Multi-Robot Self-Healing Architecture [3]

Takeaways

- ROS diagnostics is a great tool, use it!
- We identified some shortcommings:
  - Limited monitoring scope
  - Integration support
- We proposed some extensions to overcome these limits
  - Adaptive monitoring with individual priorities
  - Model support to ease the integration
  - Dynamic Baesian Networks for generic analysis
- We presented an outlook of a autonomous reactive system


Thank you
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References

[1] J. Weber, F.Wotawa: “Diagnosis and repair of dependent failures in the control system of a mobile autonomous robot”, Applied Intelligence 36, pp. 511-528, Springer (2008)

[2] M. Druzdzel: “SMILE : A Development Environment for Graphical Decision-Theoretic Models”, 16th National Conference on Artificial Intelligence, Orlando, Florida (1999)

[3] D. Kirchner, S. Niemczyk, K. Geihs: “RoSHA: A Multi-Robot Self-Healing Architecture”, 17th RoboCup International Symposium, Eindhoven, Netherlands 2013, (in review)