Intelligent, Fault Tolerant Control for Autonomous Systems

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Outline

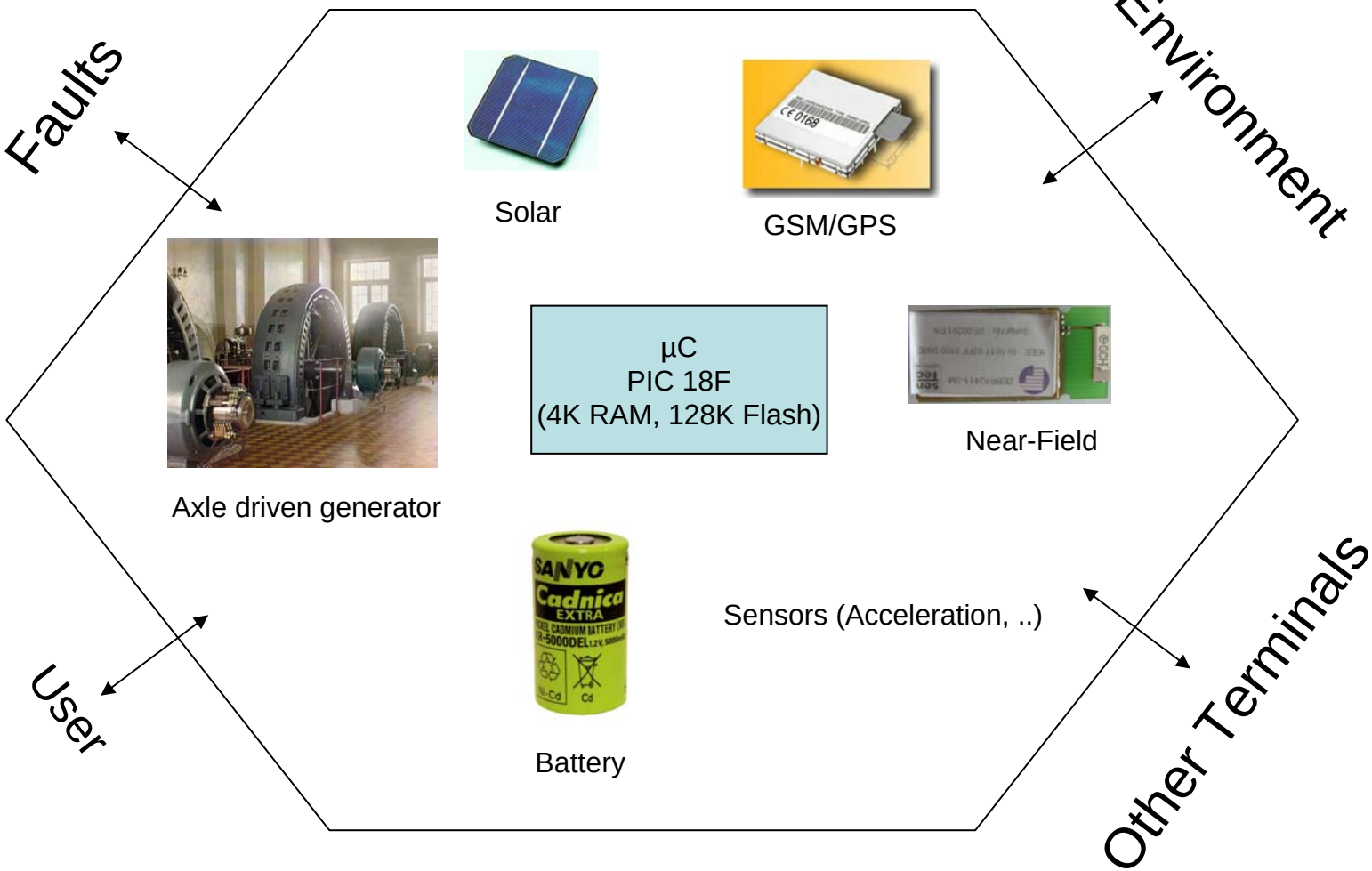
1. Motivation: "*What do we want to do? Why?*"
2. Hardware: "*How does the example platform look like?*"
3. Methodology: "*How do we attempt to solve the problem?*"
4. Results: First experiments
5. Q/A

Motivation

- What?
  - Build an autonomous system that reacts flexible and in an intelligent manner and that uses explicit knowledge
- Why?
  - Improved situational awareness
    - Environmental conditions, Internal conditions (e.g. faults, energy)
  - Fault tolerance / robustness
  - …

We want to build a system that needs less *maintenance costs*, is more *reliable* and more *flexible* than systems designed with “ordinary” approaches.

Example System



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Basic Idea

1. Rule Set
   - Describes all possible action sequences (behaviors)
   - Describes all goals the system has to reach (by employing actions)
   - Standard logic (true/false; not multi-valued)
2. Set of Activity Profiles
   - Describe the intended activity of, e.g., a goal, over time
   - Used for calculating a weight that expresses the desirability to reach the associated rule consequent
3. Algorithm
   - Search for all ways (behaviors) to reach goals by evaluating the rule set. (Evaluation must result in ‘true’ over the complete formula)
   - Sort behaviors according to weight and eliminate behaviors already chosen too often
   - Several behaviors can reach the same goal: Eliminate all but one

Basic Idea – Rule Set

- Encodes conditions for actions, action sequences, and goals.
- Assumed that an action will complete successfully whenever conditions are satisfied.
- But execution of an action is monitored:
  - Conditions can be incomplete
  - Unobservable conditions that block execution
- BNF:

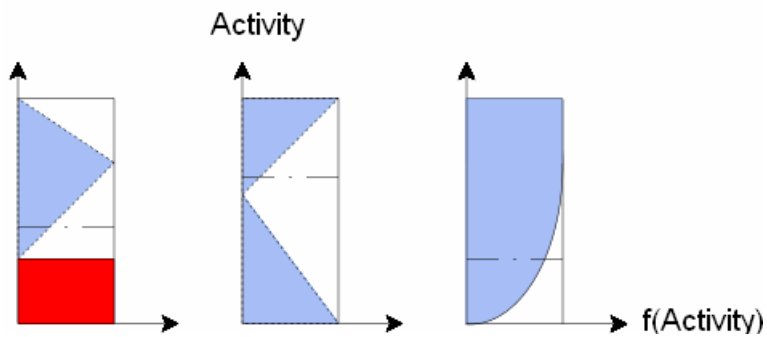
Goal := **Label** ": <=" Expression ";"
Rule := **Proposition** "<=" Expression ";"
Expression :=
(Expression "|" Expression) or
(Expression "&" Expression) or
("!" Expression) or
("Do(" **Action** ")") or
("Test(" **Proposition** ")") or
Proposition

Rule Set - Example

```
// Small rule set, controlling the example device.
LowE <= Test(Battery.Low) | Test(Battery.Crit);
HaveGuesstimatePos <= Do(COMP.GetBearing)
      & Do(BARO.GetHeight) & Do(CLOCK.GetTime);
HaveGpsPos <= not_Test(GPS.Disabled) & Do(GPS.GetPosition);
HavePosition <= HaveGpsPos | HaveGuesstimatePos;
// Goals
Goal2:  <= HavePosition & Do(NF.SendPosition);
Goal1:  <= HavePosition & Do(GSM.SendPosition);
Powersave:  <= LowE & GPS.Disabled & GSM.Off
      & CPU.ClockDown;
SwitchOnGsmPwr:  <= not_LowE & Test(GPS.Disabled)
      & GPS.Off;
SaneShutdown:  <= Test(Battery.Crit)
      & ExampleSystem.Off;
Goal0:  <= not_Test(Battery.Crit) & ExampleSystem.On;
```

Basic Idea – Set of Activity Profiles

- Forms the second order relation (“desirability”)
- Specifies a ratio for reaching a certain goal
- Examples of activity profiles:



- Weight is calculated by:

  *SlopeAtActivityFactor * DistanceToMax * (1 – DampingFactor)*

0 <= Slope, Maximum, Damping factor <= 1

Basic Idea – Algorithm (1)

- Tracks a number indicating how often a rule was run during some timeframe: Activity Factor
- Tracks a number indicating how often a rule failed: Damping Factor

- Using these factors and the knowledge base, the algorithm constantly tries to reach goals.

Basic Idea – Algorithm (2)

1. Look at the ordered list of goals: If the weight indicates a goal has to be reached goto next step. (Else look at next goal.)
2. Look at rule set; If there is a behavior that satisfies a goal goto next step. (Else look at next goal.)
3. Execute the behavior. According to execution results increment Activity and Damping Factor.
4. If steps 1 to 3 have been completed for the list of goals, recalculate the weights and goto step 1. (Else goto step 1 without recalculating weights and look at the next-best goal which still has to be examined.)

Basic Idea – Algorithm (3)

Complexity: In worst case (all goals to be reached, no behavior can be satisfied), the algorithm visits all paths encoded in the knowledge base.

Fault Tolerance: As damping factor influences weight, often failing behaviors will be penalized.

Variation of Behavior: As the activity factor influences weight, the system will choose different behaviors to reach a goal. (If the developer wants.)

Extensions

- Rules may change activity profile functions
- Classifiers that map data to propositions
- Details of these and other extensions are described in the paper

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First Experiments

- Platform:
  - Microchip PIC 18F device (4K RAM, 128K Flash)
  - FreeRTOS
  - Simulated actions, linear target activity profiles

- Results:
  - System works as intended
  - Difficulties, Open Questions
    - How choose factors so the system reacts as I want it to?
    - Are there any properties the rule set must implement?
    - (Come up with a more space efficient implementation.)

Thank you for your attention