A Reconciliation-Based Approach to Feature Conflict Resolution

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Feature Interaction Problem

Impossible to satisfy all features in a cyber-physical system (CPS)

All achievable states violate global correctness

Domains

- Autonomous & intelligent vehicles
- Internet of Things[1]

Instances

- Toyota Prius 2010[2]
  (hybrid vs. anti-lock braking systems)

Prior Work

Winner-take-all resolution

+ Conceptually simple
- Dynamic environments
- No single feature action satisfies system requirements

Synthesis-based resolution[3]

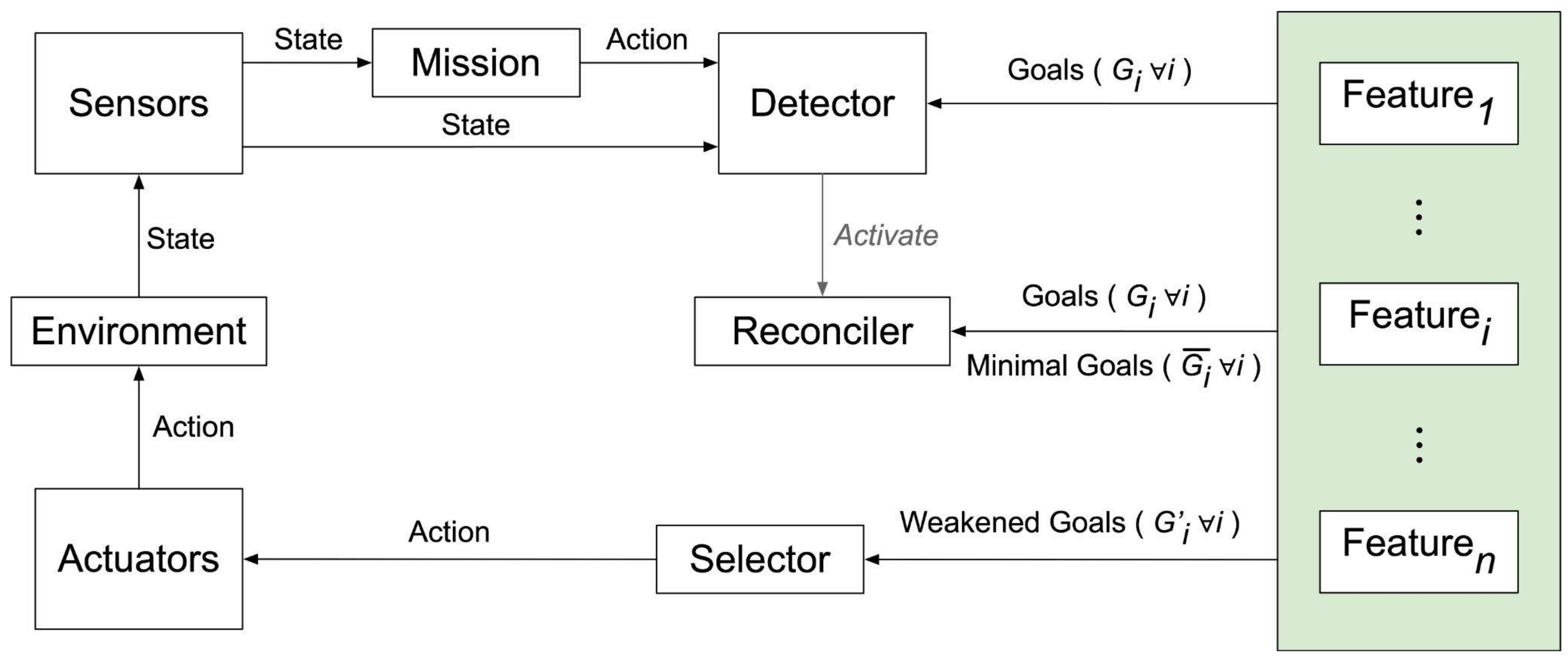
+ Dynamic environments
- Centralized (may not be resilient)
- Undermines feature autonomy
- Unable to synthesize orthogonal actions

References

1. Yarosh, S., & Zave, P. (2017). Locked or not? *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. https://doi.org/10.1145/3025453.3025617
2. CBS. (2010, March 9). *Toyota's Prius recall coming "soon"*. CBS News. https://www.cbsnews.com/news/toyotas-prius-recall-coming-soon/.
3. Gafford, B., Dürschmid, T., Moreno, G. A., & Kang, E. (2020). Synthesis-based resolution of feature interactions in cyber-physical systems. *Proceedings of the 35th IEEE/ACM International Conference on Automated Software Engineering*. https://doi.org/10.1145/3324884.3416630.

RQ: How to use the reconciliation framework to construct a controller such that the system components are dynamically reconfigurable?

Reconciliation Framework



Methods

Signal Temporal Logic (STL)

Logical formalism used to specify system requirements. Extends Linear Temporal Logic (LTL).

+ Specify requirements imposed by each feature
+ Reason about requirement satisfaction, consistency, & weakening
+ Communicate requirements between controller components
+ Improve code flexibility & reusability

Example *"Altitude between 2 & 10 meters for 4 seconds"* $\mathbf{G}_{[0,4]}(\texttt{alt} > 2 \wedge \texttt{alt} < 30)$

Mixed Integer Linear Programming (MILP)

+ Prevent over-weakening requirements
+ Problem framed in STL
+ Time-efficient dynamic reconfiguration of feature requirements

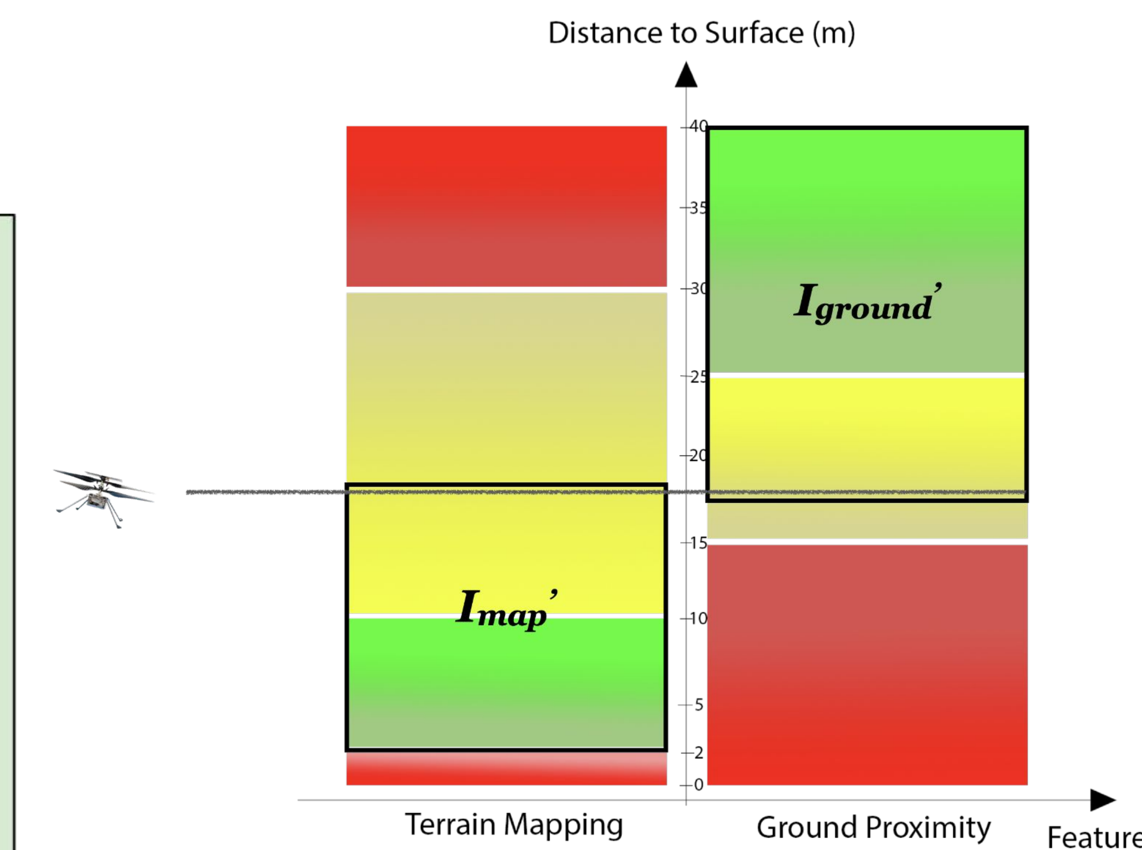
Case Study
Dragonfly Mission, Titan

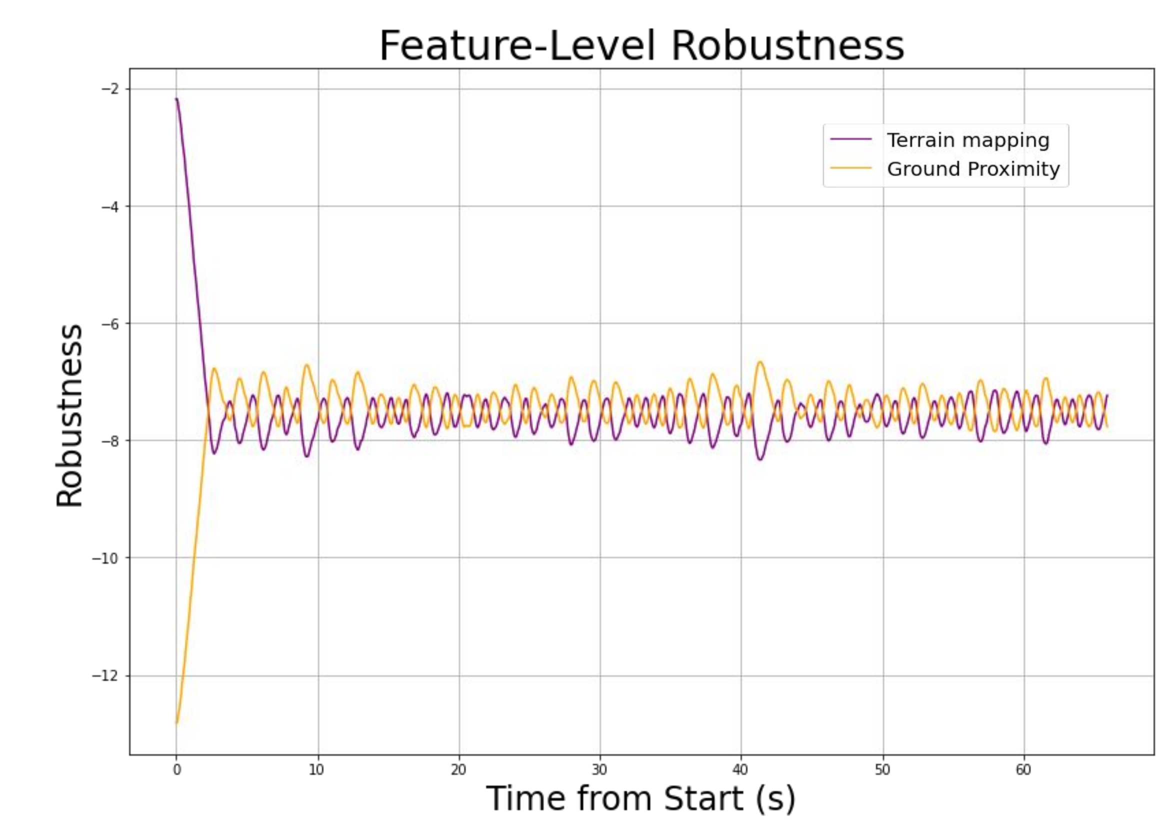
Mission

- Takeoff → Fly figure eight → Land
- Fixed 15 meter altitude

Features

- Terrain Mapping
  - Preferred: $\texttt{alt} > 2 \wedge \texttt{alt} < 10$
  - Minimal: $\texttt{alt} > 2 \wedge \texttt{alt} < 30$
- Ground Proximity
  - Preferred: $\texttt{alt} > 25$
  - Minimal: $\texttt{alt} > 15$





Future

Two-drone case study

- Multi-dimensional feature requirements
- Expanded use of STL vocabulary

Organ delivery case study

- Non-spatial dimension (battery life)