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Using the FORCE with R2U2: Adapting Robust Intervals to MLTL

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Overview

We explored improving the safety of autonomous vehicles by incorporating robustness into a temporal logic based runtime monitoring tool (R2U2).

MLTL and Robustness

MLTL is a temporal logic that operates over finite traces and bounded operators, with the minimal semantics:

$$\phi \equiv p \mid \neg\psi \mid \psi \wedge \xi \mid \psi \mathcal{U}_I \xi$$

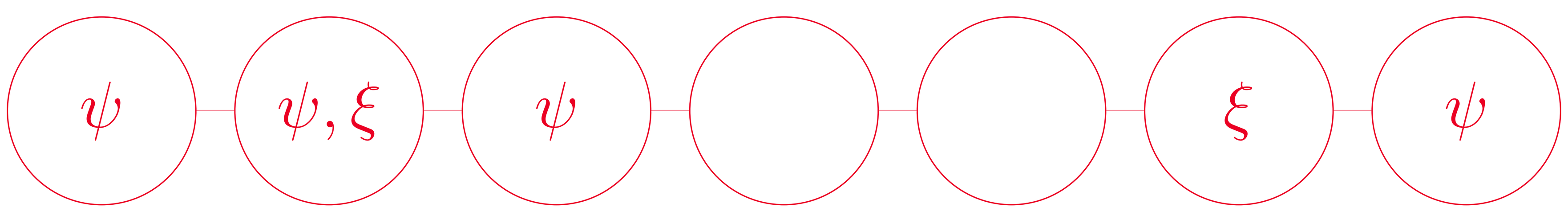

Figure 1. A sample trace for MLTL, usually denoted π

Robustness measures how much a formula is being satisfied.

We can reason about possible future robustnesses, giving us a Robust Satisfaction Interval, or RoSI.

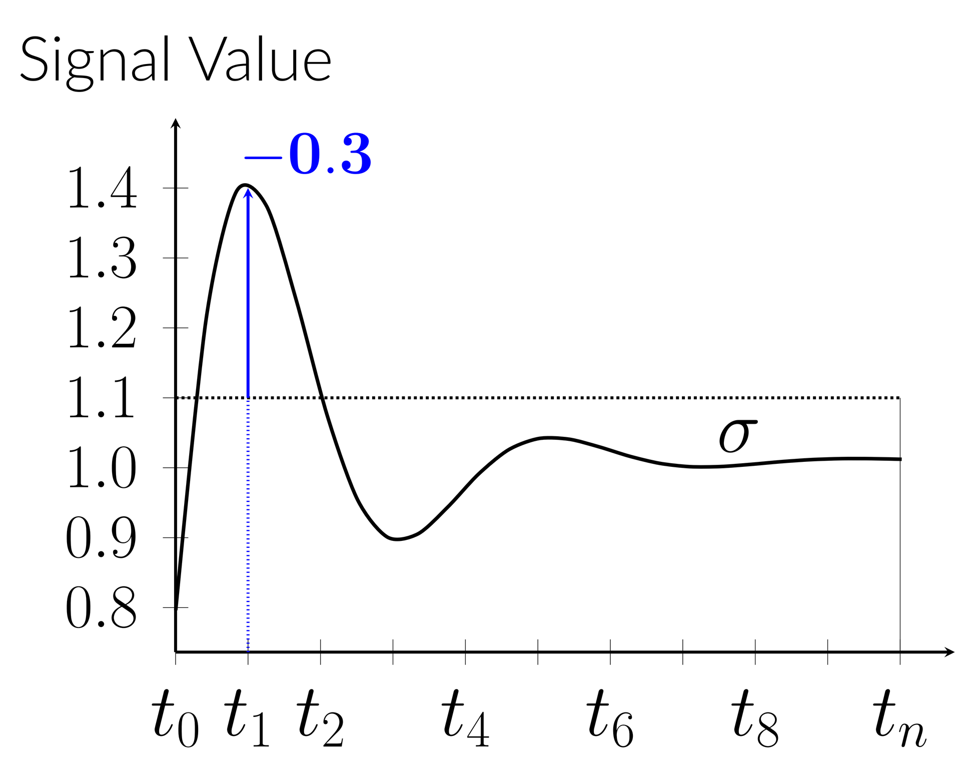

Figure 2. Robustness of the formula $\phi \equiv \Box(f(t) \leq 1.1)$

Example of Robust Intervals

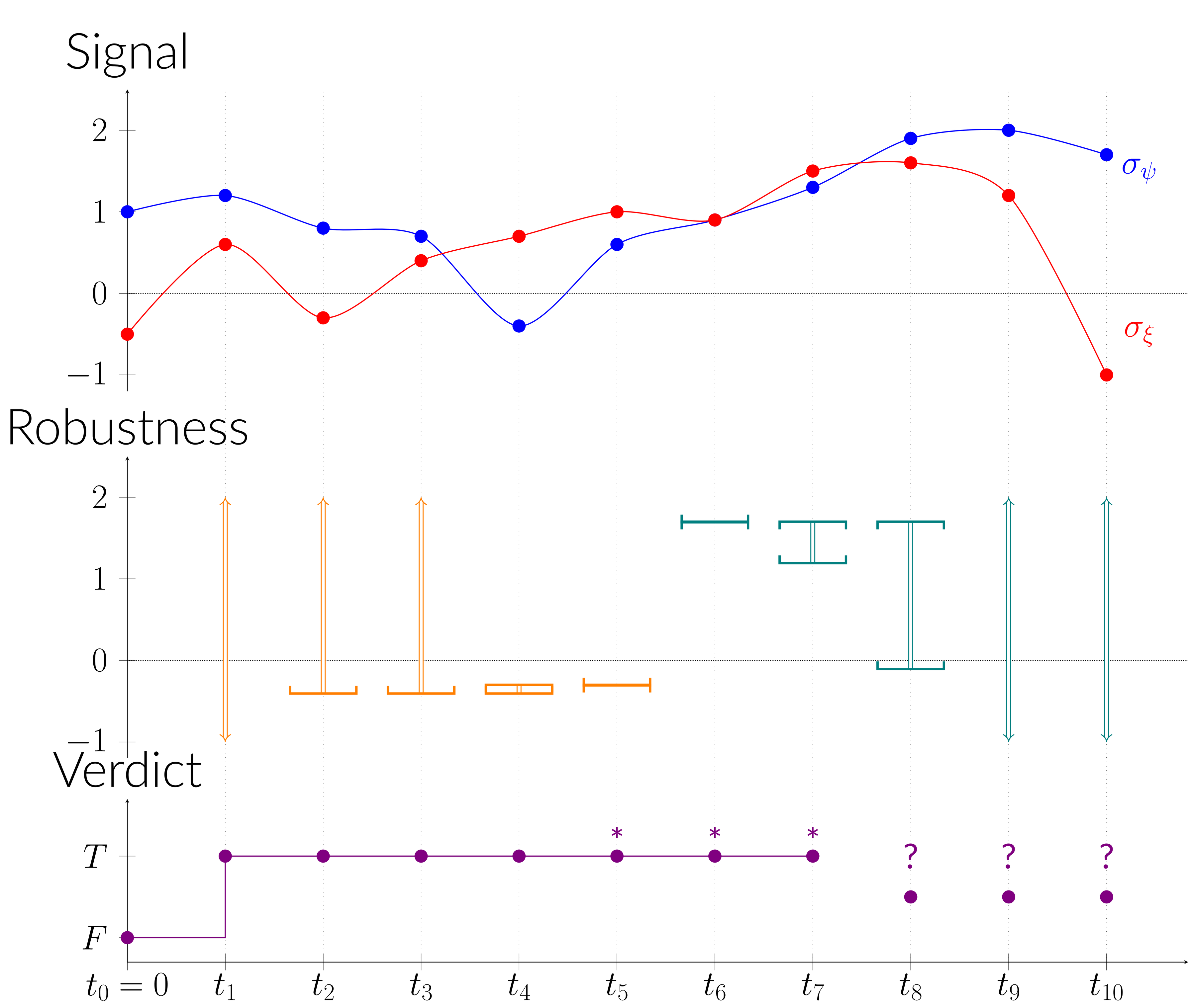

Figure 3. Signals, verdicts, and RoSIs for $\phi \equiv (\Box_{[0,3]}\psi)\, \mathcal{U}_{[2,4]}\xi$

Key Results

We can use robustness to easily calculate truth because of the following proven correspondence:

$$\rho(\Pi, \phi, t) \geq 0 \quad \Leftrightarrow \quad \pi, t \vDash \phi$$

The main theoretical result of our work comes from our ability to exactly calculate robust satisfaction intervals using the RoSI estimator function $[\rho]$.

R2U2 and New Engines

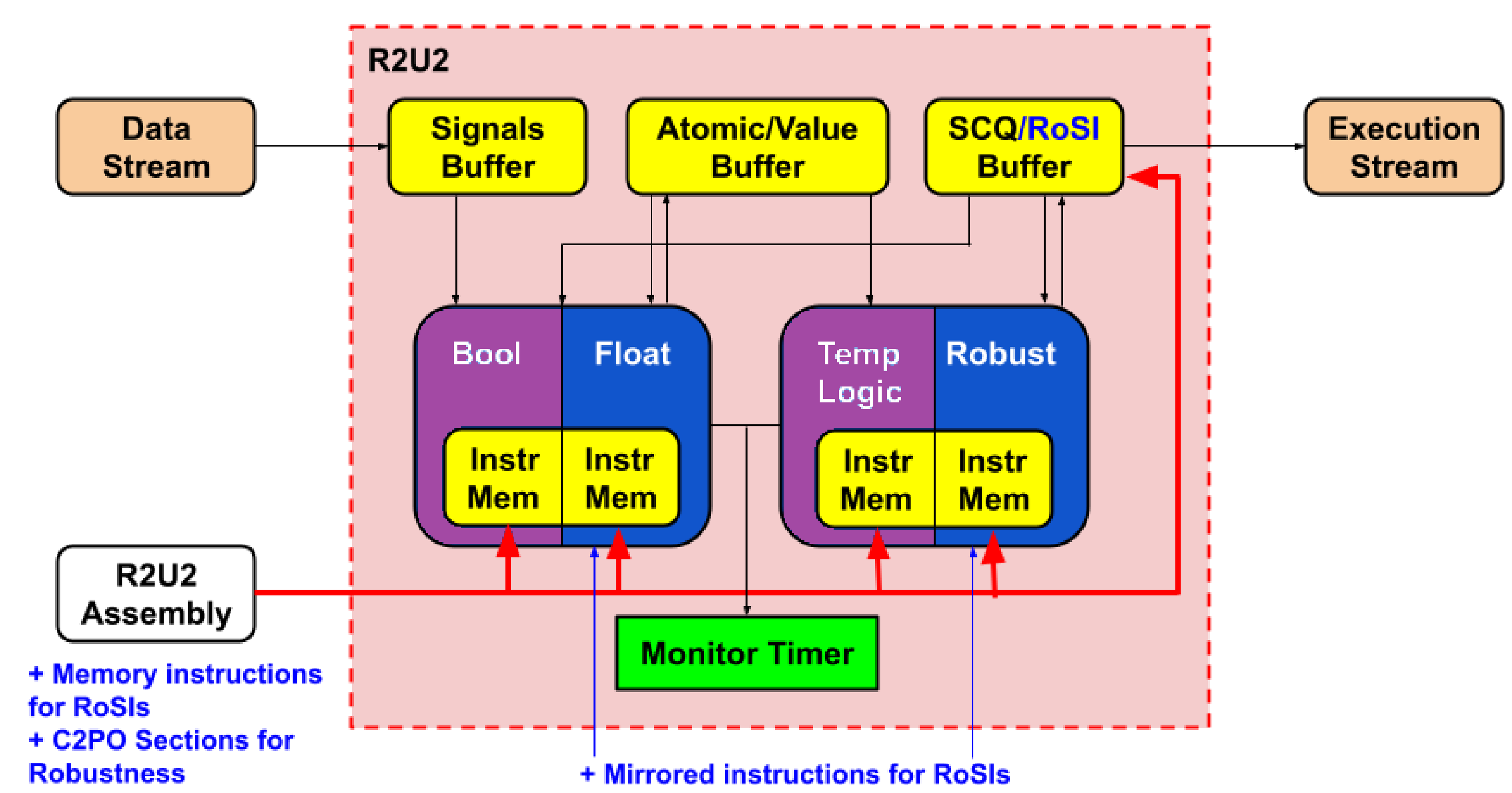

Figure 4. Functional diagram of R2U2 and new engines

FORCE Implementation

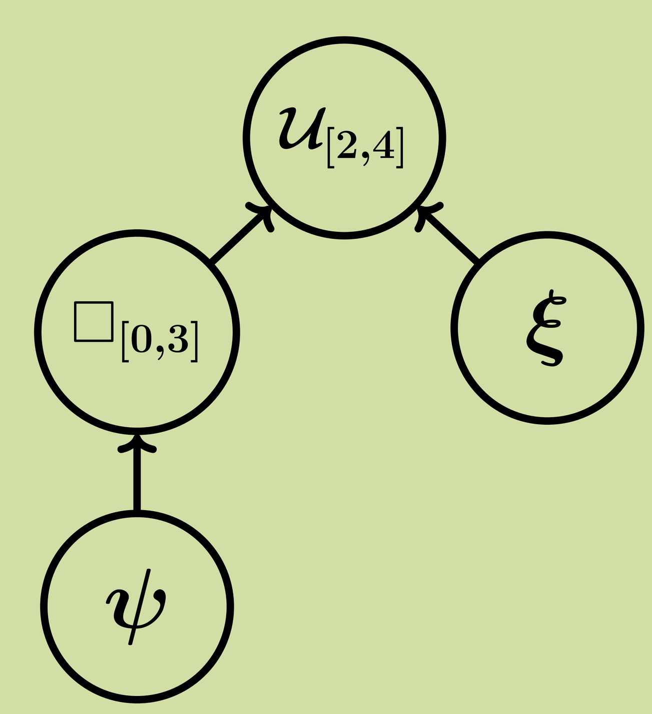

Figure 5. Abstract Syntax Tree for $\phi \equiv (\Box_{[0,3]}\psi)\, \mathcal{U}_{[2,4]}\xi$

Node Algorithm Steps:

- Discard old data from RoSI buffer.
- Read RoSIs from children.
- Perform operations/ store results.

RoSIs propagate from leaves to root

Node Operations

Node	Prop.	Not	And	Or	Until
Operation	Load	Negation	Min	Max	Max of Running Min on Signals

Future Work

- Finish the implementation of the FORCE in R2U2
- Run a thorough comparison with existing tools
- Apply to real world scenarios (autonomous drones)