9th UCAAT User Conference on Advanced Automated Testing

Keyword-Driven Simulation Testing for Open-Source Robotics

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Agenda

1) Motivation
    a) Open-source Robotics
    b) Acceptance Testing
    c) Keyword-driven Testing
2) Challenges (and solutions)
    1) Test Adaptation
    2) Time
    3) Space
    4) Continuous signals
3) Conclusion

Motivation: Open-Source Robotics

Robot Operating System (ROS)

- Message-based middleware
- Nodes provide and call services
- Nodes publish and subscribe to topics

Gazebo simulator

- 3D simulator for ROS
- Customizable through plugins

ROS

GAZEBO

Motivation: Acceptance Testing

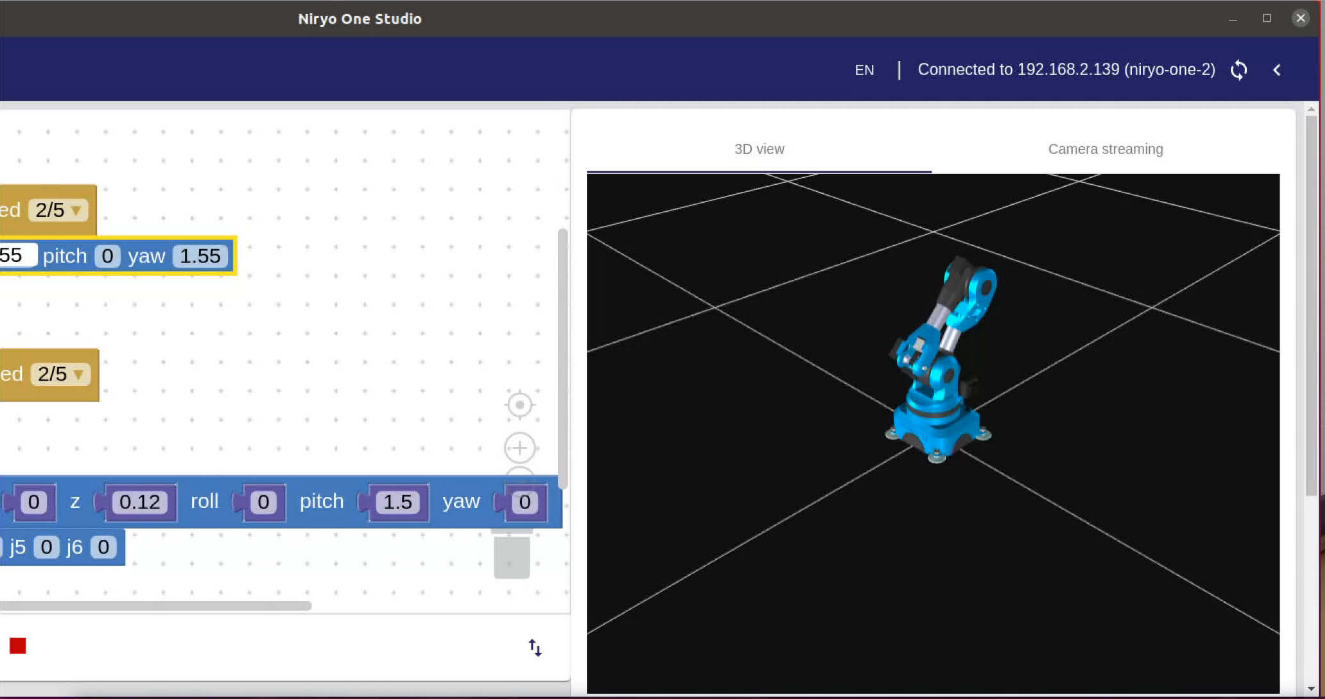
Our motivation and goals for acceptance testing:

- Lower test levels already covered for ROS (e.g. rostest for integration tests)
- Enable domain experts to write and execute test cases
- Automate test execution in simulation
- Transfer test cases from simulation to real world

Motivation: Acceptance Testing

In an acceptance test we want to ascertain that

- some things happen
  - e.g., objects, in particular robots, reach certain positions and orientations
  - in a specific timeframe
  - in a specific order
- other things DO NOT happen
  - e.g., collisions between objects, in particular robots
- certain properties hold
  - e.g., distances between objects, alignment of objects
  - remain static or
  - follow a specific course



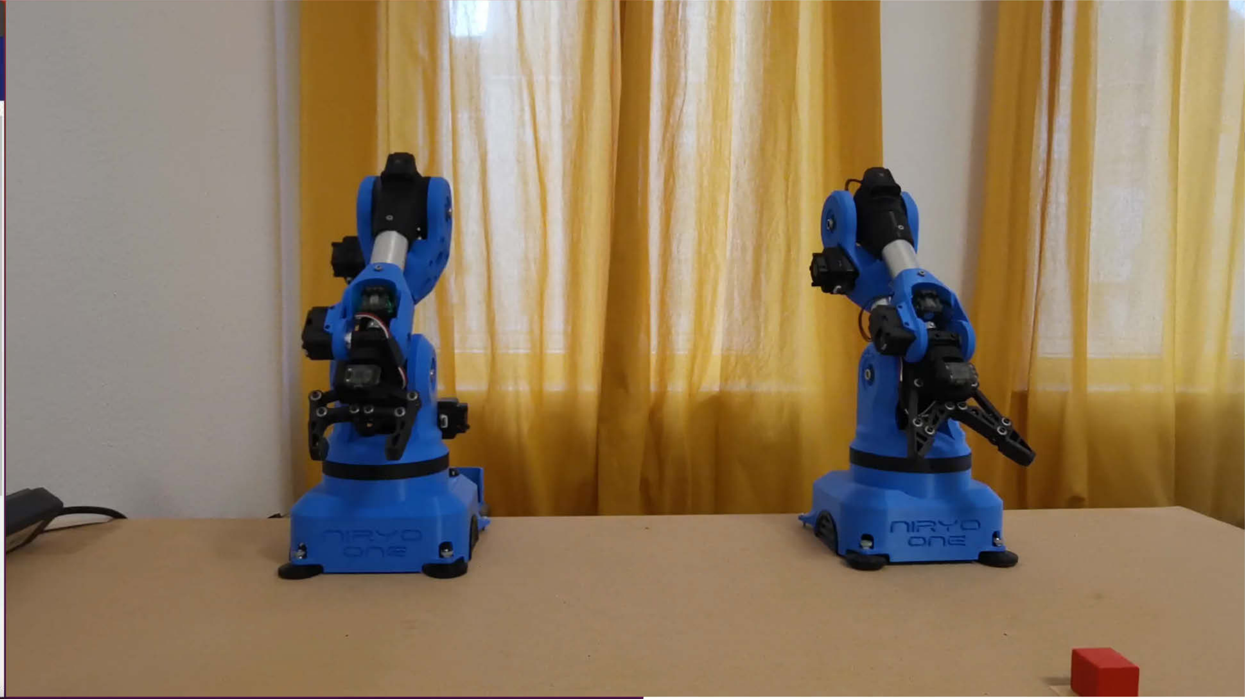
ed 2/5

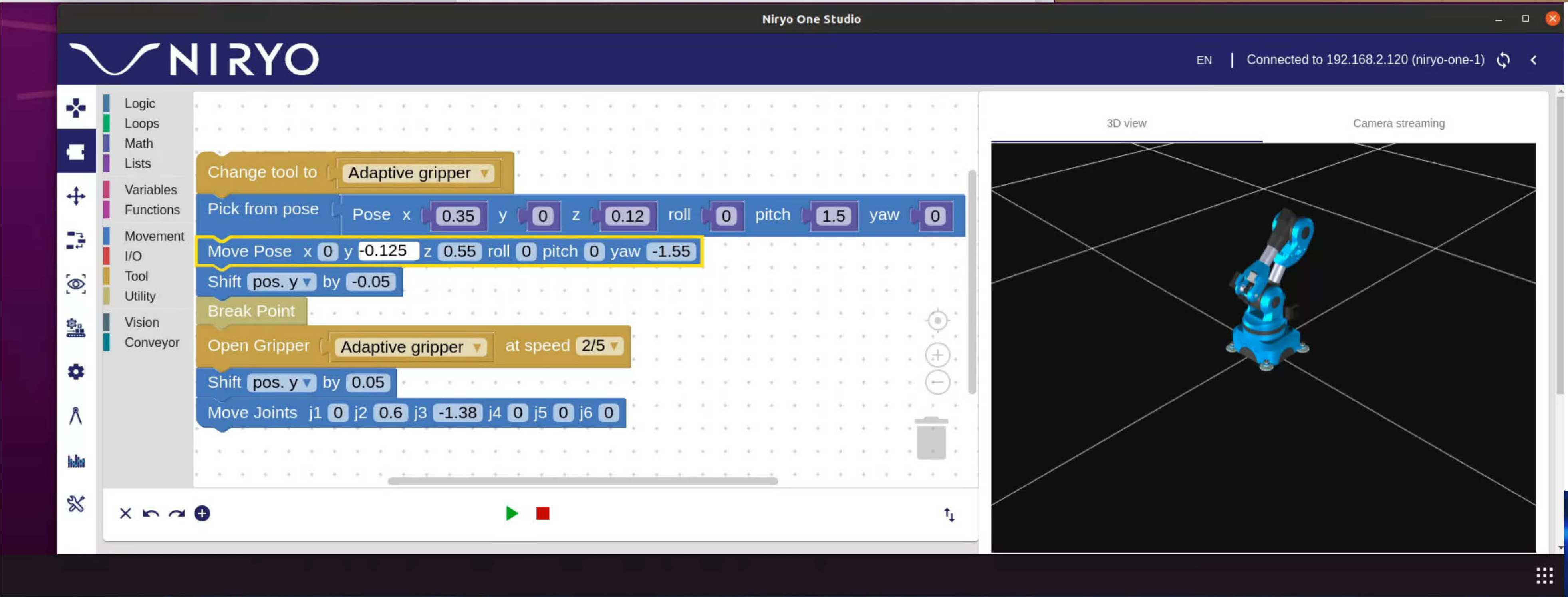
55 pitch 0 yaw 1.55

ed 2/5

0 z 0.12 roll 0 pitch 1.5 yaw 0

j5 0 j6 0





Change tool to Adaptive gripper

Pick from pose Pose x 0.35 y 0 z 0.12 roll 0 pitch 1.5 yaw 0

Move Pose x 0 y -0.125 z 0.55 roll 0 pitch 0 yaw -1.55

Shift pos. y by -0.05

Break Point

Open Gripper Adaptive gripper at speed 2/5

Shift pos. y by 0.05

Move Joints j1 0 j2 0.6 j3 -1.38 j4 0 j5 0 j6 0

Motivation: Acceptance Testing

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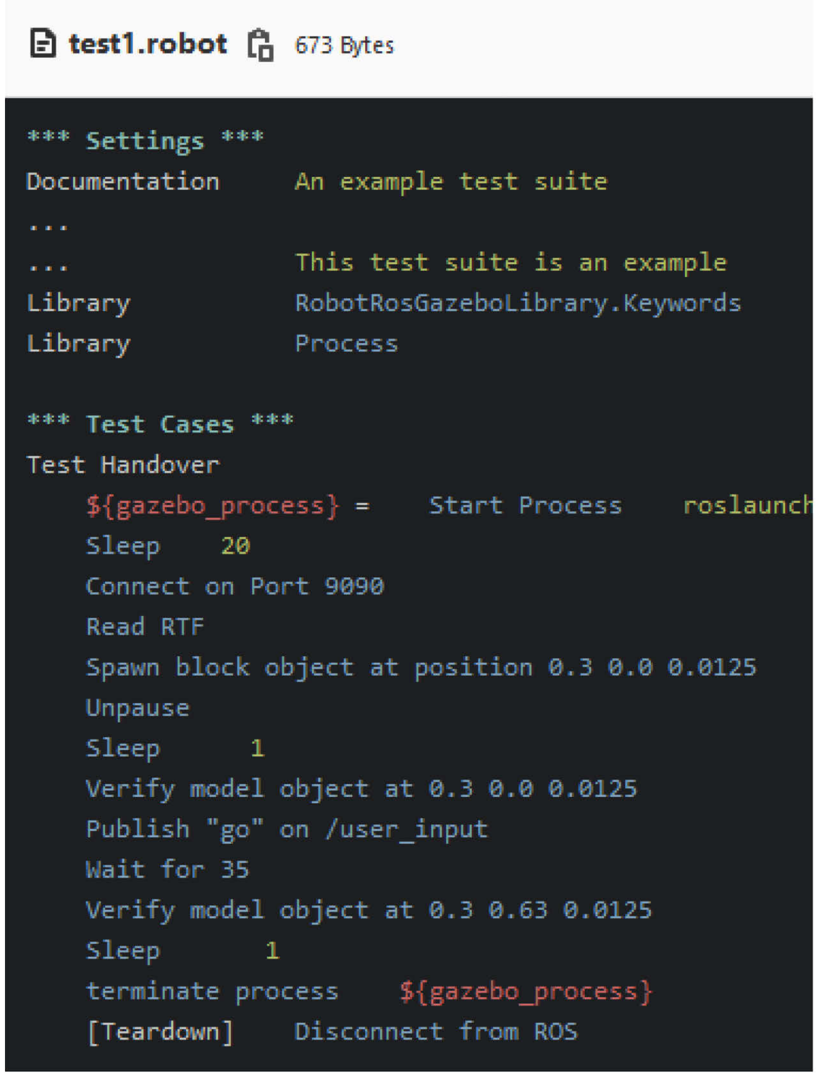
Motivation: Keyword-driven Testing

Keyword-driven testing (KDT)

- Test cases are sequences of test steps
- Test steps are expressed through keywords
- Good for interactive / event-driven / request-response systems
  - e.g., user interfaces, apps, websites, communication protocols, …
- Human-readable keywords well understood by domain experts
- Different frameworks exist
  - e.g., Cucumber, Robot, …



test1.robot 673 Bytes

```
*** Settings ***
Documentation      An example test suite
...
...                This test suite is an example
Library            RobotRosGazeboLibrary.Keywords
Library            Process

*** Test Cases ***
Test Handover
    ${gazebo_process} =    Start Process    roslaunch
    Sleep    20
    Connect on Port 9090
    Read RTF
    Spawn block object at position 0.3 0.0 0.0125
    Unpause
    Sleep      1
    Verify model object at 0.3 0.0 0.0125
    Publish "go" on /user_input
    Wait for 35
    Verify model object at 0.3 0.63 0.0125
    Sleep       1
    terminate process    ${gazebo_process}
    [Teardown]    Disconnect from ROS
```

Challenges

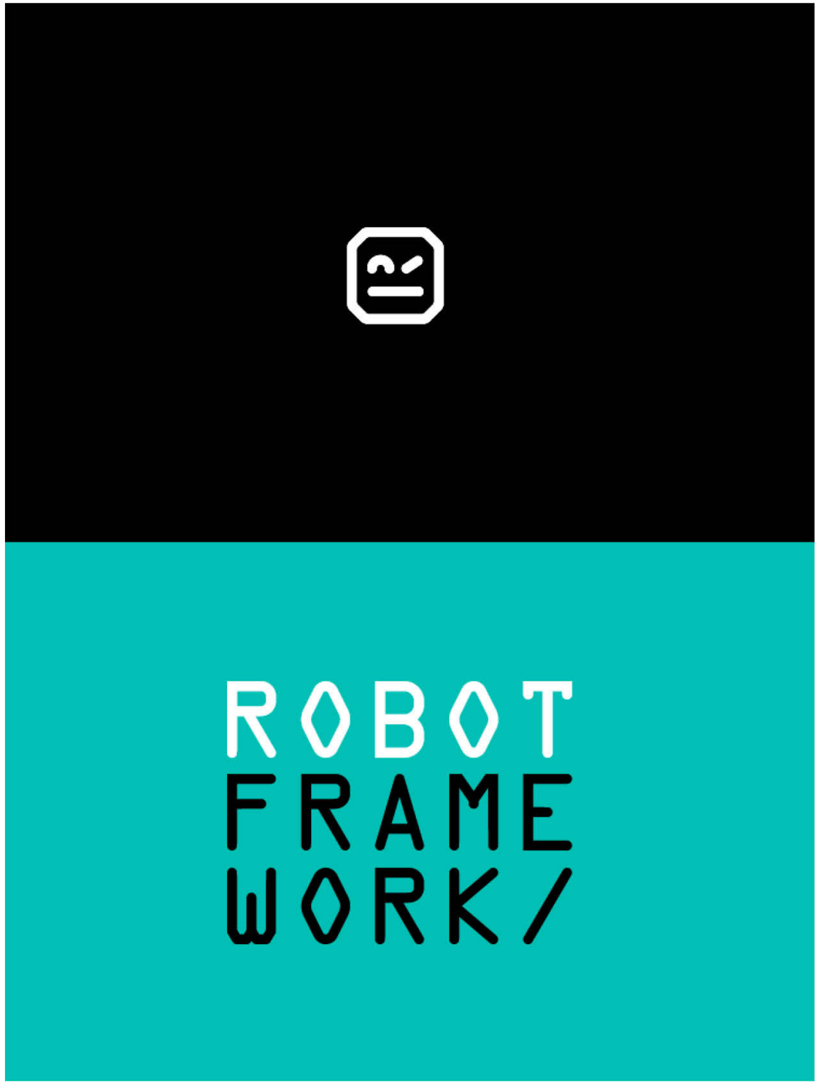
When applying KDT to robotics and simulation, we faced challenges with

- Test Adaptation: defining and accessing the test interface
- Time: simulation time vs. wall-clock time
- Space: position and orientation of objects
- Continuous signals: stimuli and observations

Test Adaptation

Custom library for the Robot Framework

- Convenience keywords for ROS
  - Launch ROS launch configurations (roslaunch) and run ROS scripts (rosrun)
  - Read and write ROS parameters (rosparam)
  - Call ROS services (rosservice)
- Gazebo specific keywords
  - Start, pause, reset simulation
  - Spawn, delete, inspect objects
- More to come, available from GitHub:
  - hielsnoppe/robotframework-rosgazebolibrary



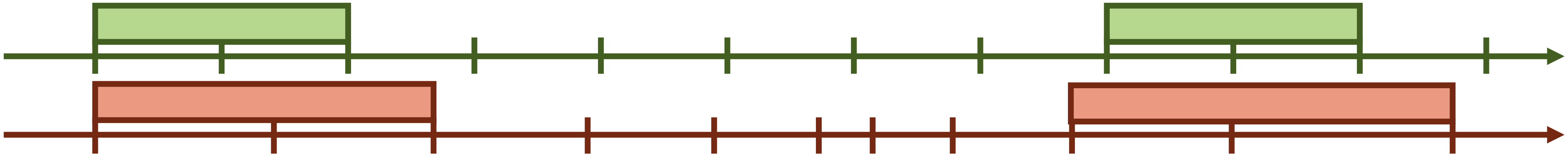
Time

There is a disparity between simulation time and wall-clock time

- Expressed as the real-time factor (RTF) in Gazebo
- The RTF fluctuates over time
- RTF often < 1.0 due to low performance / high load
- RTF > 1.0 when simulating at an accelerated tempo (on high performance device)

Possible solutions:

- Check simulation time in a loop (naïve busy waiting)
- Adaptive timeouts and intervals (less busy waiting, but still…)
- Simulator plugin for timeouts and intervals



Time: Simulator Plugin

Simulator plugin

- Advertise four ROS services:
  - Set timeout (duration): timeout handle
  - Clear timeout (timeout handle)
  - Set interval (duration): interval handle
  - Clear interval (interval handle)
- Advertise one ROS topic:
  - /timeouts_intervals
- Publish respective handle whenever a timeout or interval is due

Keyword library

- Subscribe to topic

Keywords

- Wait {duration}
  - Call set timeout (duration)
  - Proceed when receiving handle
- Repeat Every {duration}
  - Call set interval (duration)
  - Perform action when receiving handle

Space

Check position and orientation of objects

- Absolute (e.g., moving robots)
- Relative to other objects (e.g., distances, alignments, collisions)

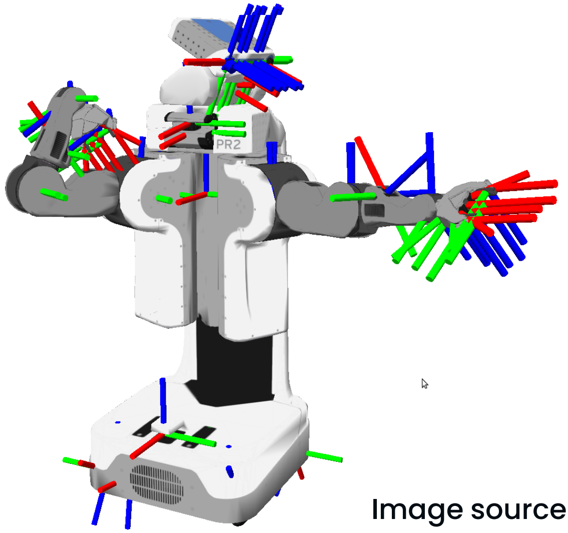


Image source: http://wiki.ros.org/tf2

How to implement?

- Service to request absolute object positions exists in Gazebo
- tf2 library calculates relative positions and orientations
- static_transform_publisher from tf2_ros monitors and publishes relative positions and orientations
- Run such node for every watched relative position and subscribe to topic

Collisions

Keywords

- Ignore Collision [qualifier]?
- Fail On Collision [qualifier]?
- Log Collision [qualifier]? [As {level}]?
- Expect Collision [qualifier]
- Where [qualifier] is
  - Between {group of links}
  - Involving {group of links}

How to implement?

- Internal topic for collisions exists in Gazebo
- Create Gazebo plugin to publish topic externally
- Subscribe to topic, set listeners for conditions according to keywords

Continuous stimuli and observations

How to express (continuous) change over time in a sequence of keywords?

- Sample stimuli from mathematical functions
- Trace observed properties and evaluate later
- Register watchers on observed properties and react to specific events

Continuous stimuli

Keywords

- Sample {signal} From {function} At {interval}
- Where {function} is a function (t: Time) → Any, e.g.,
  - Step: jump to value
  - Impulse: jump to value and back
  - Ramp (linear, sinus): transition to value over time
  - Periodic: modulate signal periodically
  - Custom functions?
- Inspired by MTCD from Model Engineering Solutions

How to implement?

- Custom ROS node or
- parallel thread in test execution
- To be determined!

Continuous observations

Keywords

- Trace {expression}: {watcher handle}
- Log {condition} As {level}: {watcher handle}
- Fail On {condition}: {watcher handle}
- Expect {condition}: {watcher handle}
- Relieve Watcher {watcher handle}
- Where
  - {expression} is a function (s1: Signal, …, sN: Signal) → Any
  - {condition} is a function (s1: Signal, …, sN: Signal) → Boolean

How to implement?

- Subscribe to respective topics
- Evaluate expressions and conditions on every update
- Unsubscribe topics when watchers are relieved

Conclusion

Keyword-driven Simulation Testing for Open-Source Robotics

- Basic functionality provided by open-source library
- Some aspects benefit from simulator plugins, e.g.,
  - Simulation time-based timeouts and intervals
  - Spatial relationships via tf2 transforms
- Advanced features still experimental, e.g.,
  - Collision checking
  - Continuous stimuli and observations

Any further questions?

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