RobotRaconteur®

Robot Raconteur Version 0.8: An Updated Communication System for Robotics, Automation, and the Internet of Things

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http://robotraconteur.com

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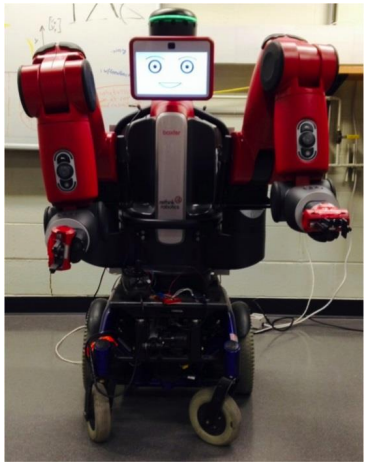
Introduction

Language, platform, and transport independent communication system for Robotics and Automation Systems

- Compatibility
  - 22 platforms/architectures
  - 7 languages
  - 5 transport technologies
- "Plug-and-Play", "Instant-On" capability
- "Augmented Object-Oriented" model
- Transactional, streaming, and "most recent"
- Client-service and service-client
- TLS, certificates, and password security
- Compatible with Web and Cloud
- Node and service discovery
- Version 0.8 ready for commercial use



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Motivation

A new robot and Kinect in the lab;

or multiple spectrally controllable lights, multiple spectral sensors, and multiple cameras;

or multiple robots with individual controllers and force/torque sensors …

How to get them to talk each other and program and control them?

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Design Objectives

- Peer-to-peer client-service communication
- Ease of use
  - Minimal “boiler-plate” software development
  - Automatic type generation at runtime or design-time
  - Model similar to “object-oriented” systems
  - Rapid modification of services
- Maximum compatibility between devices over long timespan
  - Decades, not months of compatibility
- High performance, low latency
- Industry standard security (TLS, certificates, etc.)
- Automatic service discovery
- Asynchronous operation
- Minimal dependencies

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Choices of Distributed Architectures

- General Purpose (using Remote Procedure Call, RPC)
  - Distributed Component Object Model (DCOM) ➔ .NET Remoting
  - Java Remote Method Invocation (RMI) ➔ Common Object Request Broker Architecture (CORBA)
- Robotics
  - Robot Operating System (ROS)
  - Data Distribution Service (DDS)
  - ZeroMQ/Protobuf (Ignition Transport)

- Expose functions or objects across network boundary
- Transparency achieved through serialization
- Some platform dependency

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Compatibility

- Platforms/architectures
  - Windows (x86, x64)
  - Linux (x86, x86_64, ARM hard-float, ARM soft-float, PowerPC, MIPS
  - Mac OSX
  - Android (ARM, x86)
  - iOS
  - Web Browser (Chrome, IE, Edge, Firefox, Safari)
  - ASP.NET Web Server
  - Linux PREEMPT_RT
  - MathWorks xPC Target
  - Particle Photon embedded device
  - Arduino embedded device
- Languages
  - C++, C#, Java, MATLAB, JavaScript, LabView
- Transports
  - TCP, Local, Cloud, USB, PCIe
- Compatibility constantly expanding, grey are experimental

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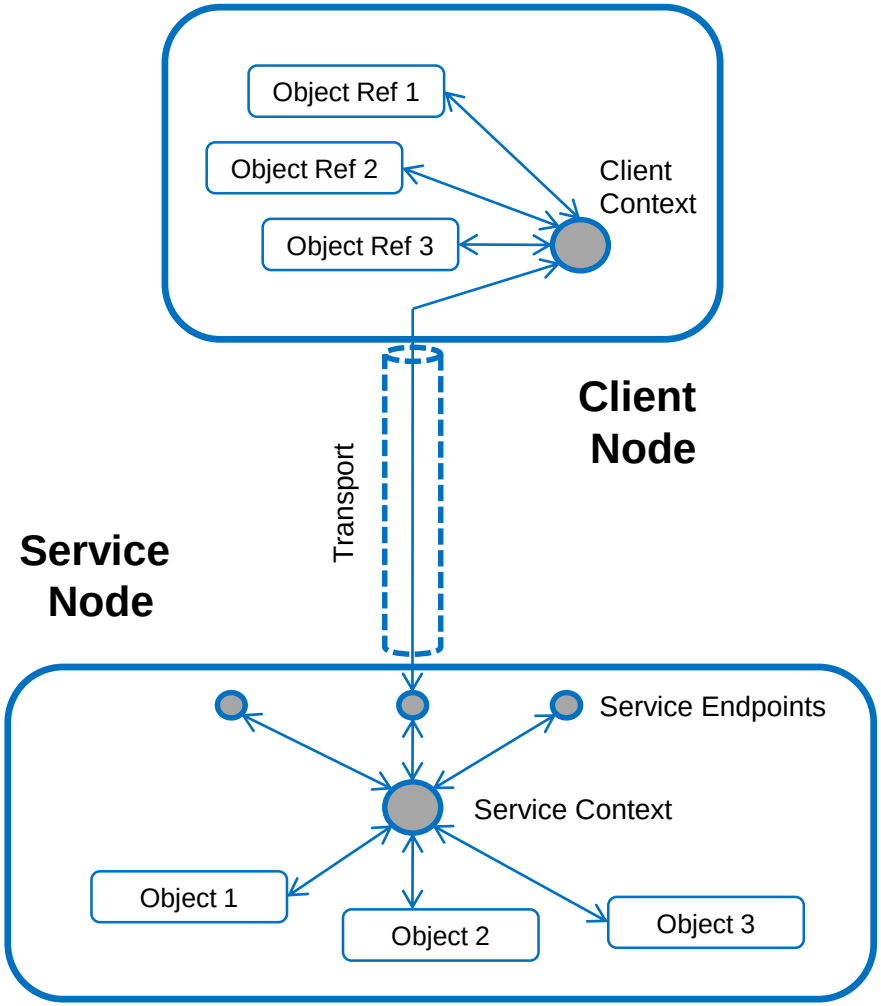
Client-Service Model



- Service: Base object reference with members, and references to other objects.
- Service definition file: Define object and structure members
- Supports try/catch error transmission across boundary

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Augmented Object-Oriented Model

- Object types are defined in service definitions
- Member types:
  - Property
  - Function
  - Event
  - ObjRef (Object Reference)
  - Pipe
  - Callback
  - Wire
  - Memory
- Can use “import” to use structures and object types in other service definition
- “implements” statement used in object to inform clients that it is compatible with previous service definition version

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Supported Value Types

- Value types always serialized and sent to the remote node
- Primitive Types
  - double, single, int8, uint8, int16, uint16, int32, uint32, int64, uint64, string
  - Single dim arrays of numeric types (ie double[])
  - Arrays can be fixed, variable, or have a maximum size (double[10], double[], double[10-]
- Structures defined within service definitions
  - Contains “fields” of other primitives
- Maps with int32 or string
  - (double{int}, string{string}, mystruct{string}, double[]{string}
  - Dictionary in C#, cell in MATLAB
- Lists
  - (double{list}, string{list}, mystruct{list}, double[]{list}
  - List in C#, cell in MATLAB
- Multidimensional complex or real array (double[*])
- varvalue – wildcard value type

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Example Robot

- iRobot Create 1
- Raspberry Pi 3 ARM Computer
- Dual Webcams
- Power Converter
- Camera Mast and Cover
- Exposes two services
  - iRobot Create control
  - Webcam control and acquisition

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iRobot Create Service Definition

```
#Service to provide sample interface to the iRobot Create

service experimental.create

option version 0.5

struct SensorPacket
    field uint8 ID
    field uint8[] Data
end struct

object Create
    option constant int16 DRIVE_STRAIGHT 32767
    option constant int16 SPIN_CLOCKWISE -1
    option constant int16 SPIN_COUNTERCLOCKWISE 1

    function void Drive(int16 velocity, int16 radius)
    function void StartStreaming()
    function void StopStreaming()

    property int32 DistanceTraveled
    property int32 AngleTraveled
    property uint8 Bumpers

    event Bump()

    wire SensorPacket packets

    callback uint8[] play_callback(int32 DistanceTraveled, int32 AngleTraveled)
end object
```

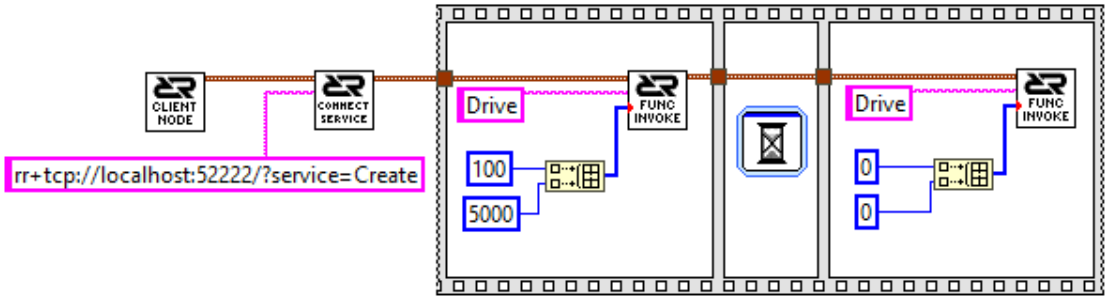
Example Clients

```python
from RobotRaconteur.Client import *
import time

obj=RRN.ConnectService('rr+tcp://localhost:52222/?service=Create')

obj.Drive(100,5000)
time.sleep(1)
obj.Drive(0,0)
```

Python

```matlab
o=RobotRaconteur.Connect('rr+tcp://localhost:52222/?service=Create');
o.Drive(int16(100),int16(5000));
pause(1);
o.Drive(int16(0),int16(0));
```

MATLAB



LabVIEW

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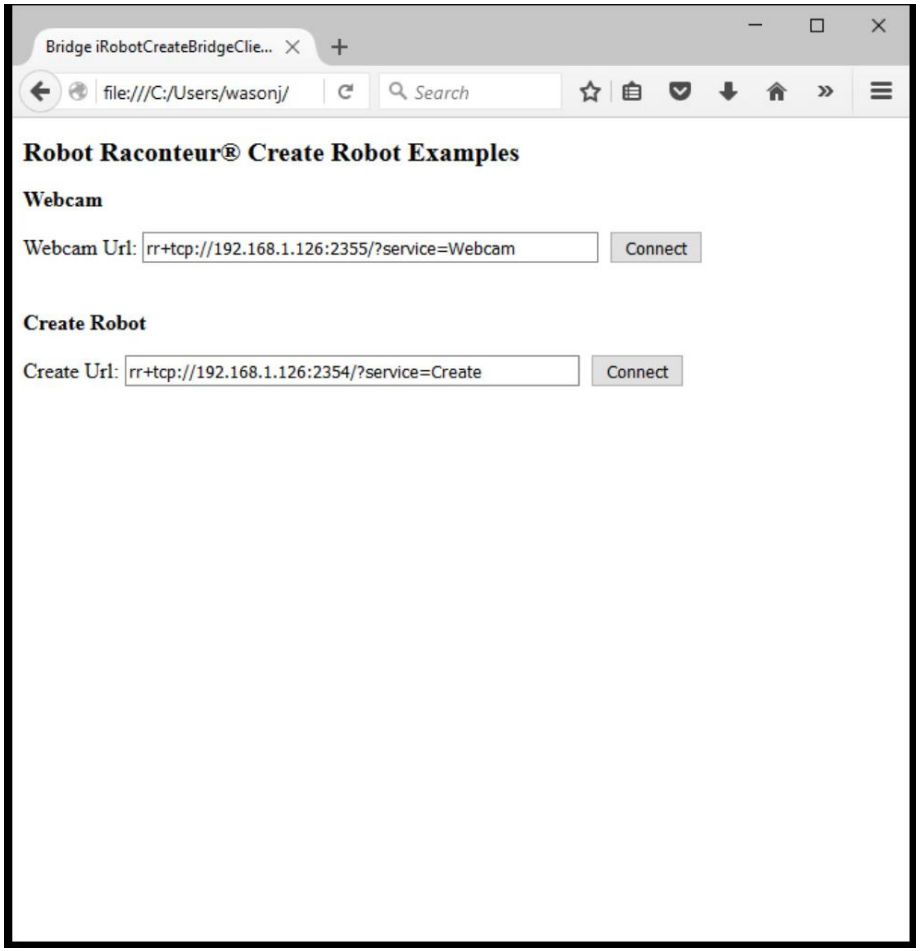
Web Browser Client Video



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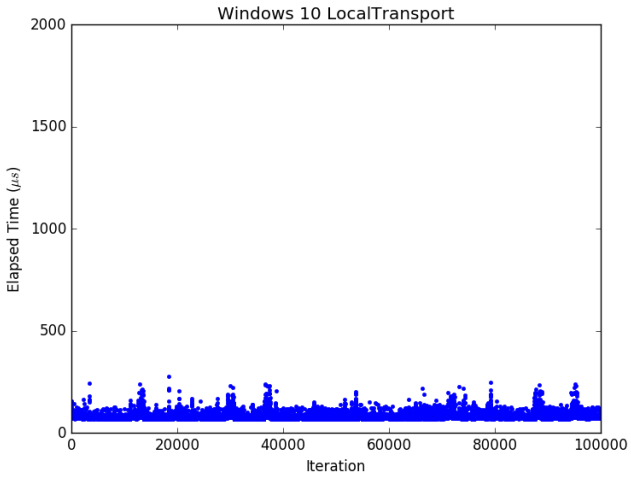
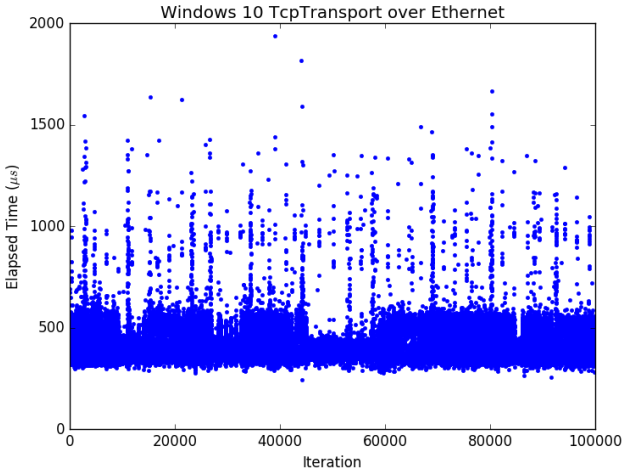
Performance





Configuration	Mean (μs)	Min (μs)	Max (μs)	σ
Windows 10 `LocalTransport`	77.1	66.4	275.9	8.9
Windows 10 `TcpTransport` Loopback	113.1	102.2	683.7	10.5
Windows 10 `TcpTransport` with TLS Loopback	141.2	128.6	931.8	12.6
Windows 10 `TcpTransport` over Ethernet	417.4	243.5	3754.9	84.7
Windows 10 `TcpTransport` with TLS over Ethernet	492.7	306.0	5859.8	79.9
Ubuntu 14.04 `LocalTransport`	136.6	126.8	956.3	8.2
Ubuntu 14.04 `TcpTransport` Loopback	166.7	151.3	1674.1	8.8
Ubuntu 14.04 `TcpTransport` with TLS Loopback	278.0	264.1	1481.4	7.9
Ubuntu 14.04 `TcpTransport` over Ethernet	518.0	303.3	7449.7	32.6
Ubuntu 14.04 `TcpTransport` with TLS over Ethernet	687.3	477.4	1605.7	47.5
Ubuntu 14.04 ROS TCP Loopback	1848.8	1362.7	14325.544	883.2

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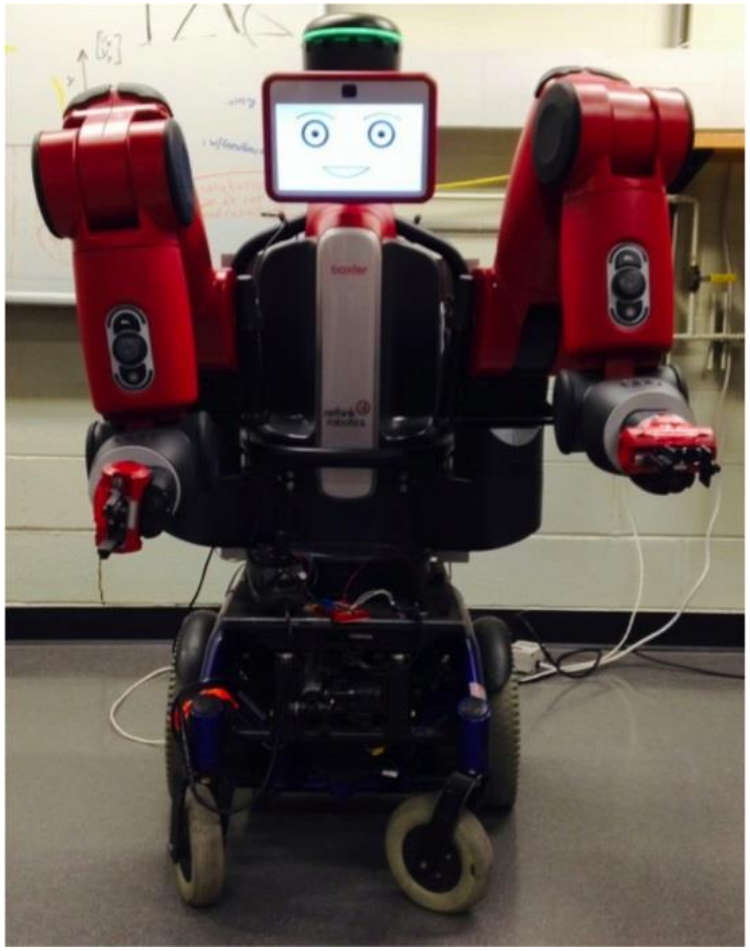
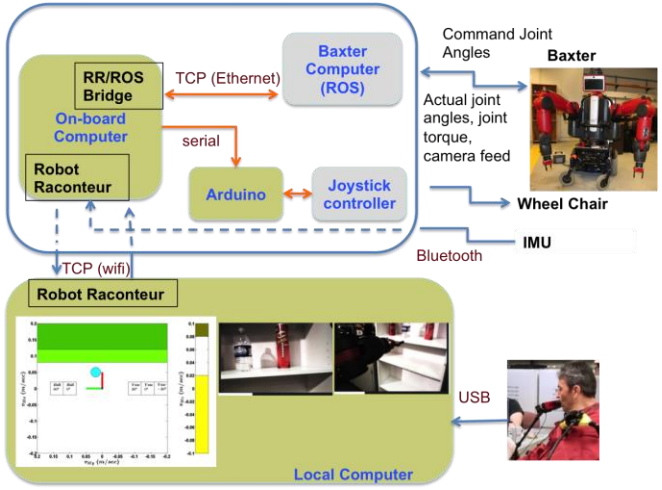
Baxter on Wheels

- Baxter robot with Wheelchair
- Used with a JamBoxx controller for disabled support experiments



Center for Automation Technology and Systems, Rensselaer Polytechnic Institute, Troy NY



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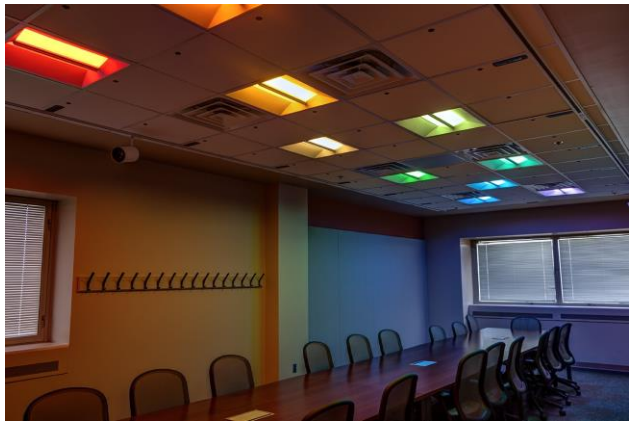
Smart Conference Room

- Designed to test next-generation lighting control algorithms
- Color-tunable lights
- Light color sensors
- Depth cameras
- Climate control
- Uses Robot Raconteur for communication between components



Smart Lighting Engineering Research Center,
Rensselaer Polytechnic Institute, Troy, NY

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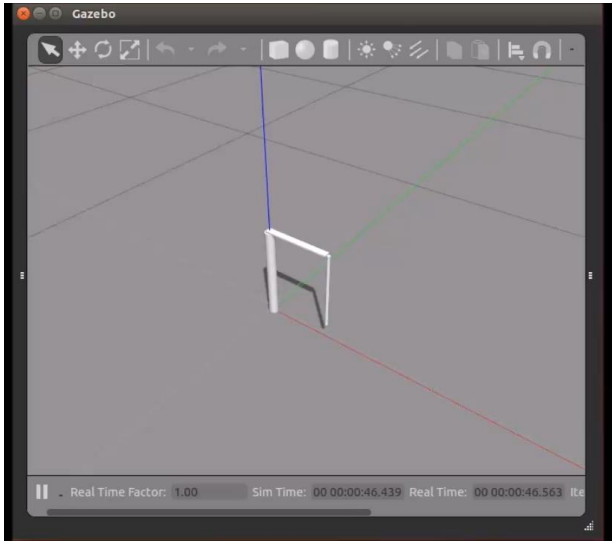
Gazebo Robot Simulator Plugin



- System level Server plugin
- Provides Object-Oriented interface similar to internal C++ API
- Does not require modifying robot or world SDF files
- Access to world, controllers, and sensors
- Capable of soft real-time control

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License

- Commercial license, Royalty Free for most uses
- Open Source projects are prone to:

Ecosystem Fragmentation

- Open Source projects tend to fork or have poor quality versions
  - Not a problem for most projects, but can be fatal to a distributed system
- Fragmentation examples:
  - Crypto-currency
  - Android
  - HTML/JavaScript
- Organizational model based on other commercial consortiums
  - USB, PCI-SIG, EtherCat, CANopen, etc.

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Conclusion

- Robot Raconteur is a powerful communication library for system integration
- Provides “plug-and-play” capability
- Numerous advantages over existing technology
- Significant use at Rensselaer Polytechnic Institute and other university/research centers around the world
- Future work:
  - Hardware transports
  - Cloud transports
  - Real-time communication
  - Support for additional platforms/languages
  - Industrial consortium with standardization committee

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Acknowledgement

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