Institute of Mechanism Theory, Machine Dynamics and Robotics

RWTH AACHEN UNIVERSITY

This thesis was submitted to the Institute of Mechanism Theory, Machine Dynamics and Robotics

Cross-Compiling ROS2 Humble to WebAssembly

Master Thesis

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Aachen, 31 March 2023

Master Thesis

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Cross-Compiling ROS2 Humble to WebAssembly

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Formula symbols and indices

Lower case latin letters as formula symbols

Upper case latin letters as formula symbols

Lower case greek letters as formula symbols

Upper case greek letters as formula symbols

Indices

List of abbreviations

General abbreviations

1. Introduction

1.1. Robot Operating System 2

1.2. Motivation

2. Literature Review

2.1. State of the Art

2.1.1. ROS on Web

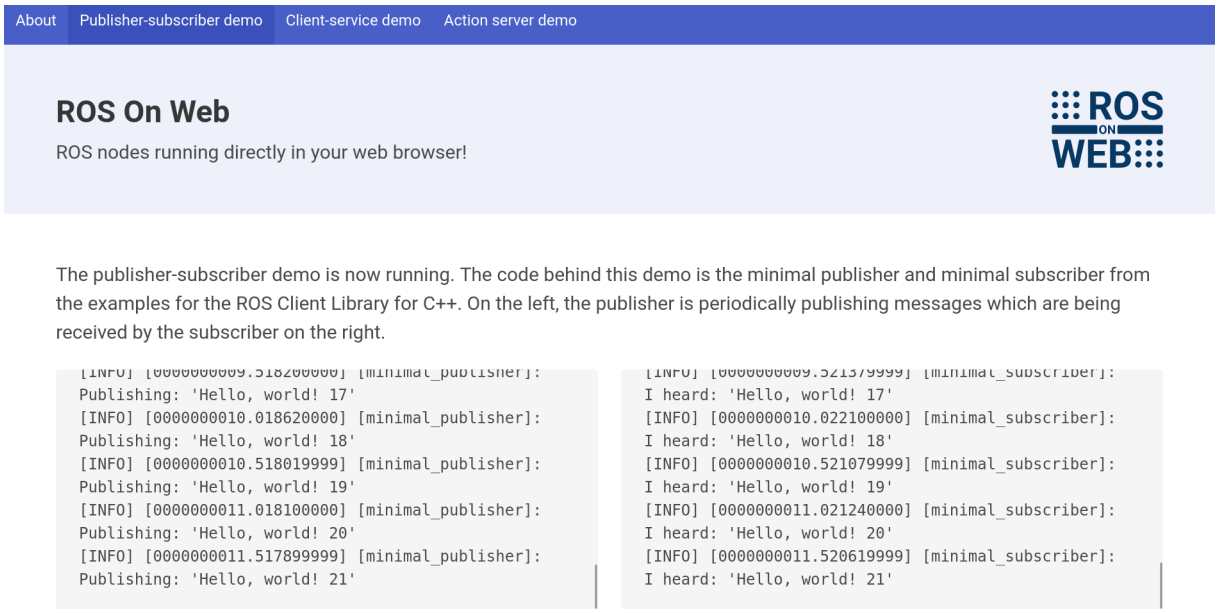

Figure 2.1. *ROS on Web* publisher and subscriber demo

Advantages and disadvantagesss

Not open source

ROS1 or ROS2

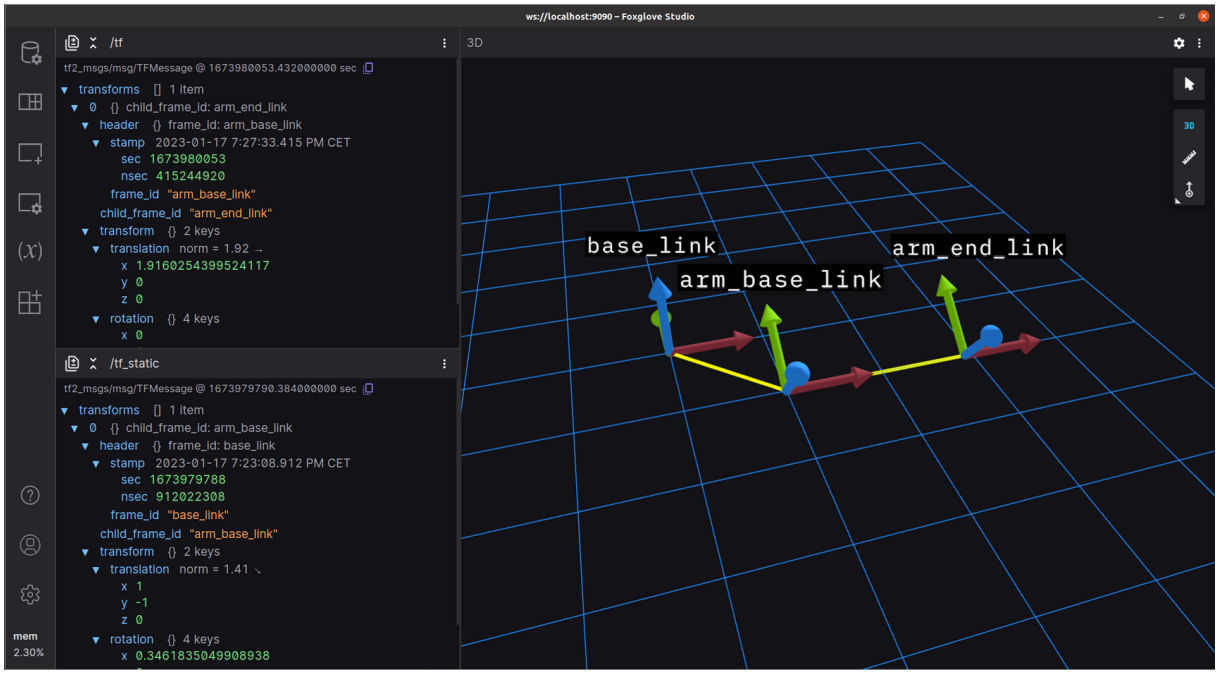

Figure 2.2. Visualizing ROS 2 Transforms with Foxglove Studio

2.2. Relevant Works

2.2.1. ROSbridge

2.2.2. ROS Control Center

2.2.3. ROSboard

2.2.4. ROSlink

2.2.5. Foxglove Studio

2.3. State of WASM

2.3.1. Unity in WebAssembly

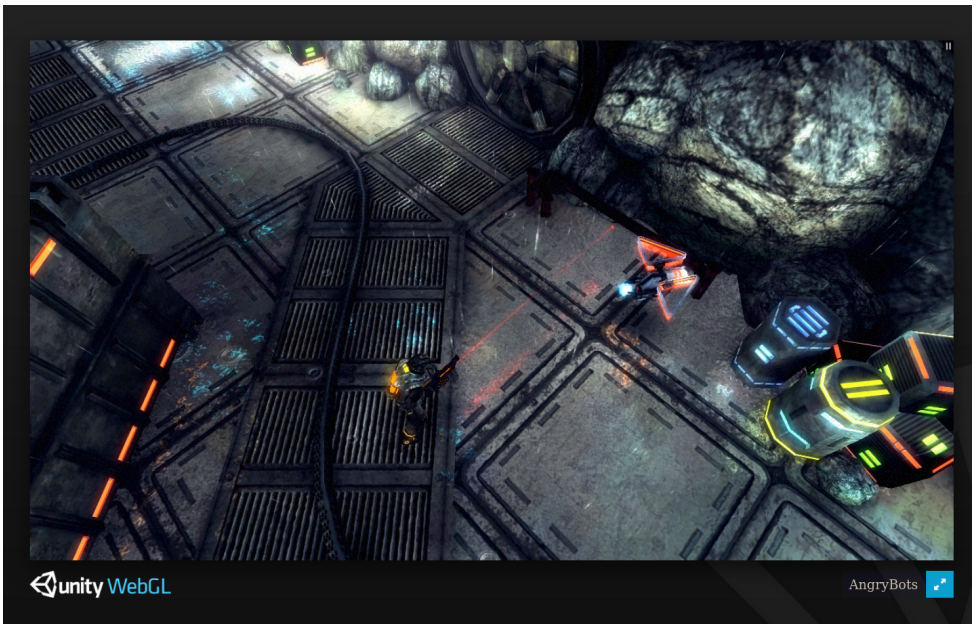

Figure 2.3. Demo of Angry Bots in Unity WebGL

3. Concept Realization

3.1. Concept

Goals: - open source

Ideal scenario: - click on a link and run ROS - connect to a robot via bluetooth - share simulations and algorithms

3.2. Implementation Layers

3.2.1. User Levels

Table 3.1. TODO:

User	Description
Beginners	Complete beginners who have never used ROS or programmed in any language.
Students	University students with minimal programming experience.
ROS Users	Students and researchers who actively use ROS for projects.
Roboticists	Robotics software developers including contributors to the ROS ecosystem.

3.2.2. User Levels of Interaction

Table 3.2. TODO:

UI Level	Description
Non-interactive	Nodes run automatically as soon as the site is launched.
Minimal	User can start/stop 1−2 nodes by pressing a button.
Basic	User can select which nodes to run and can analyze the environment by requesting or viewing information.
Intermediate	The graphical interface allows the user to accomplish primary tasks, such as displaying a robot.
Advanced	A complete GUI where the user has full control of the environment, can start/stop nodes, modify params, interact with robots, etc.
Complete	All ROS 2 features are available and packages can be built on the browser

3.2.3. Technical Levels

Table 3.3. TODO:

Level	Description
L0	A publisher is displayed.
L1	A publisher and subscriber can communicate with each other and offer minimal interaction to start and stop each node.
L2	Multiple nodes and distinct topics with limited interaction.
L3	Graphical display and interaction with a ROS client library.
L4	Manipulation of a phisycal robot wirelessly.
L5	Visualization of a robot with Zethus.
L6	Simulation of a robotics scenario with Gazebo.
L7	Development workspace for creating and debugging ROS packages.

3.3. Scope

Middleware replacement (why sockets don't work)

JavaScript "ROS master"

4. Methodology

- Development environment - Building tools - Testing tools (chrome, firefox)

4.1. Development Environment

4.2. Cross-Compilation Tools

4.3. Testing Environment

5. Middleware Implementation

- What does the middleware do? - ROS supported middleware implementations - Why it needs to be replaced - Minimal implementation (minimal set of functions) - Design of middleware packages (tree diagram or something)

5.1. DDS Middleware

5.1.1. FastDDS

default

5.1.2. Eclypse

5.1.3. Gurum

5.2. Custom Middleware

5.2.1. Email

5.2.2. Zenoh

5.3. Substituting ROS 2 Middleware

At run time

At build time

5.4. Custom Middleware Design

6. Package Building Process

- Emscripten - Colcon - Toolchains

7. Design of Web Elements

7.1. Web Workers

7.1.1. Communication Channels

7.2. Message Queues

- Web workers, what are they? why are they needed? - Communication channels - Registry of topics/subs/pubs - Message handling

8. Package Management and Distribution

- Automating package building - robostack?

9. Concept Assessment

- Survey - Performance measures - Limitations

10. Summary

11. Outlook

- Compiling on the browser - Packaging Gazebo - WASI

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