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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Contents

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

GUI	Graphical User Interface
ROS	Robot Operating System
URDF	Universal Robotic Description Format
WASM	Web Assembly

1. Introduction

1.1. Robot Operating System 2

Robot Operating System (ROS) 2

1.2. Motivation

Web Assembly (WASM)

2. Literature Review

2.1. State of the Art

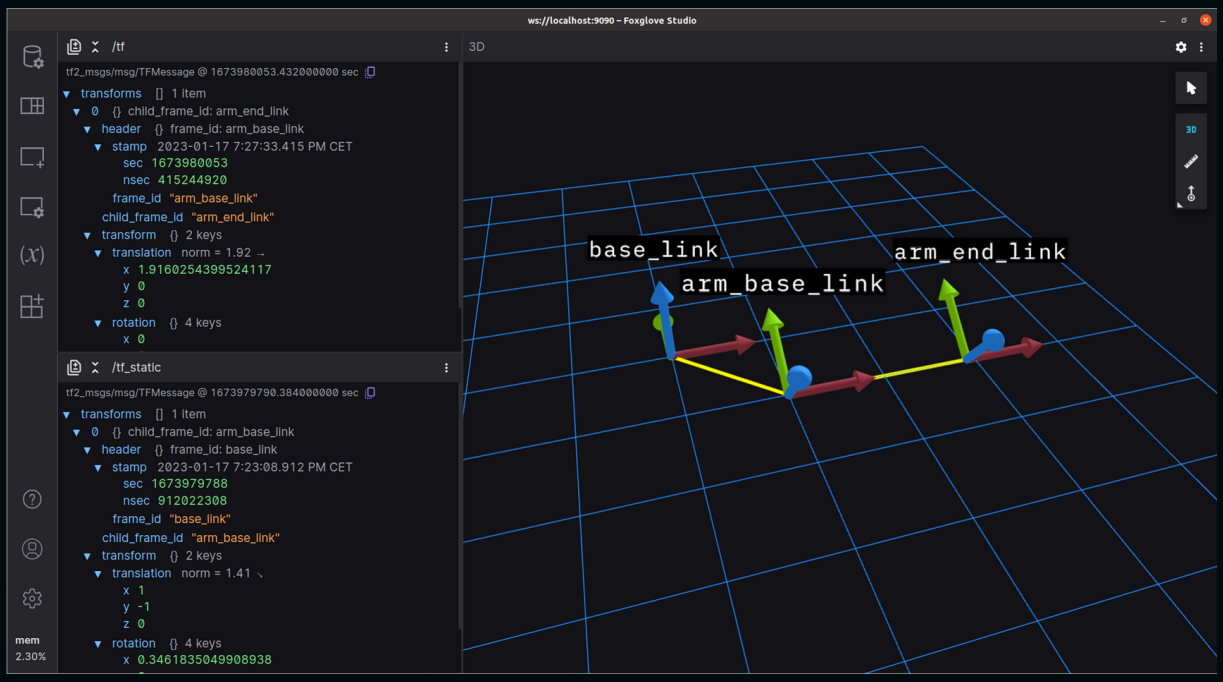
2.1.1. ROS on Web

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

Advantages and disadvantages

Not open source

ROS1 or ROS2



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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

Introduce the concept

ROS

The goals for this project can be defined by an *target scenario* in which a high level of usability is reached by an intermediate user. First, an intermediate user is described as an individual who is familiar with the ROS ecosystem but does not have the need to maintain or test ROS packages across different platforms. In the target scenario, this intermediate user will be capable of performing the following tasks:

- install pre-compiled ROS 2 packages in the browser
- launch nodes including publishers, subscribers, servers, and clients
- interact with the environment to obtain information about running nodes, this would include echoing topics, listing parameters, reviewing log files, etc.
- visualization of Universal Robotic Description Format (URDF) files, transforms, point clouds, markers, etc.
- playing and recording bag files
- connecting with robots via bluetooth

3.2. Implementation Layers

3.2.1. User Levels

Table 3.1. Target users categorized by expertise level.

	User	Description
0	Beginner	Complete beginners who have never used ROS or programmed in any language.
1	Student	University students with basic programming experience.
2	ROS User	Students and researchers who actively use ROS for projects.
3	Roboticist	Robotics software developers including contributors to the ROS ecosystem.

3.2.2. User Levels of Interaction

Table 3.2. User interface segmented based on the level of interaction.

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

3.2.3. Technical Levels

Table 3.3. Implementation categories with increasing technical difficulty.

Level	Description
0	A publisher is displayed.
1	A publisher and subscriber can communicate with each other and offer minimal interaction to start and stop each node.
2	Multiple nodes and distinct topics with limited interaction.
3	Graphical display and interaction with a ROS client library.
4	Manipulation of a physical robot wirelessly.
5	Visualization of a robot with Zethus.
6	Simulation of a robotics scenario with Gazebo.
7	Development workspace for creating and debugging ROS packages.

3.3. Scope of Implementation

3.3.1. Middleware Replacement

3.3.2. User Interface

3.3.3. Automatic Builds

3.3.4. Out of Scope

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

6.1. Environment

6.2. Tools

6.3. Post Processing

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

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