Lab 1 – R-IDE Product Description

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1. Introduction

Automation and robotics are increasingly becoming the new norm in many facets of life. Semi-autonomous vehicles are on roads and highways, robotic arms appear in factories and warehouses, and vacuum cleaners can clean without human intervention. Robots and autonomous machines are here to stay within society.

As an industry, robots and autonomous machines are expected to grow substantially. The mobile robots market is expected to grow at 24% per year from $19 billion in 2018 to $23 billion by 2021 and further to $54 billion in 2023 (Cardona et al., 2020).

Robot Operating System (ROS) is an open-source set of tools and software libraries to help build robotics applications. ROS is made up of topics and messages and facilitates communication between components. These topics and messages can be recorded into a ROSbag file that can be played back or logged for future use. Messages can also be sent to visualization tools and can allow developers to work with an entirely simulated robot. ROS supports common components such as cameras, LIDAR, and motor controllers. These components are identified within ROS as nodes and can be visually displayed as a node graph. Most applications require many nodes.

ROS has an estimated market value of $270 million as of 2020 (*Market Reports*, 2022), with projected growth to $280 million in 2028 and $460 million in 2032 (*Future Market Insights*, 2022). ROS has been utilized in industries such as autonomous vehicles, aerospace, healthcare, and agriculture. ROS has been utilized by organizations such as NASA (“Lunar Rover”) (Wessling, 2022), Microsoft (Ackerman, 2021), and Sony (Fujita, 2018).

While ROS has seen extensive use, development with ROS remains a challenge for many. In particular, the user interface and experience for ROS can be a significant hurdle for newcomers. Since most ROS projects involve many ROS nodes and each node is controlled through a separate terminal, this can quickly clutter screens, and can be difficult to differentiate one process from another. Similarly, it can be difficult to identify when nodes interact with each other. When users search for documentation to solve these issues, they come upon articles that can be over 10 years old, along with unhelpful descriptions and sometimes even missing pages entirely. All of this contributes to the difficulties in building and maintaining a ROS project.

R-IDE (ROS Integrated Development Environment) is an extension pack designed to improve the user experience when developing ROS applications. Hosted on the Visual Studio Code extension marketplace, R-IDE provides tools and functionalities that simplify common tasks and commands, enable visualization tools, and organize the user’s workspace. By taking advantage of R-IDE, developers can quickly build simple projects and have access to various template files to implement. R-IDE users can easily navigate source code and data to build, fix, and test ROS projects.

2. Product Description

R-IDE is an extension pack for VScode designed to simplify and speed up the development lifecycle and learning process for building ROS applications. It utilizes wizards, templates, IntelliSense, and snippets to help developers build products faster while including visualization features and ROSBag interfaces to help test and validate their systems.

2.1. Key Product and Features

The key features of R-IDE are its simplified user interface and quick setup, along with the addition of visualization features embedded directly into the integrated development environment (IDE). The primary tools involve code manipulation and completion. R-IDE uses wizards to create new files and update the relevant compilation and package files. R-IDE also takes advantage of tools natively in VSCode to allow users to autocomplete common code patterns. Most common tasks and actions are simplified to a button click or menu. This simplified user interface reduces the need for overreliance on outdated documentation.

Visualization tools allow developers to manage and conceptualize the reality of what the components of their project currently accomplish and can hint towards improvements. Developers can publish messages to topics to test how their system behaves on a set of known data points and build models and algorithms to handle any case.

2.2. Major Components (Hardware / Software)

R-IDE consists mainly of the developer environment within the VSCode IDE. It is comprised of multiple modular extensions packaged together into a single extension pack. R-IDE takes advantage of the tools that exist in VSCode, such as Microsoft's ROS extension to provide features such as syntax highlighting and commands to control ROS software inside the IDE.

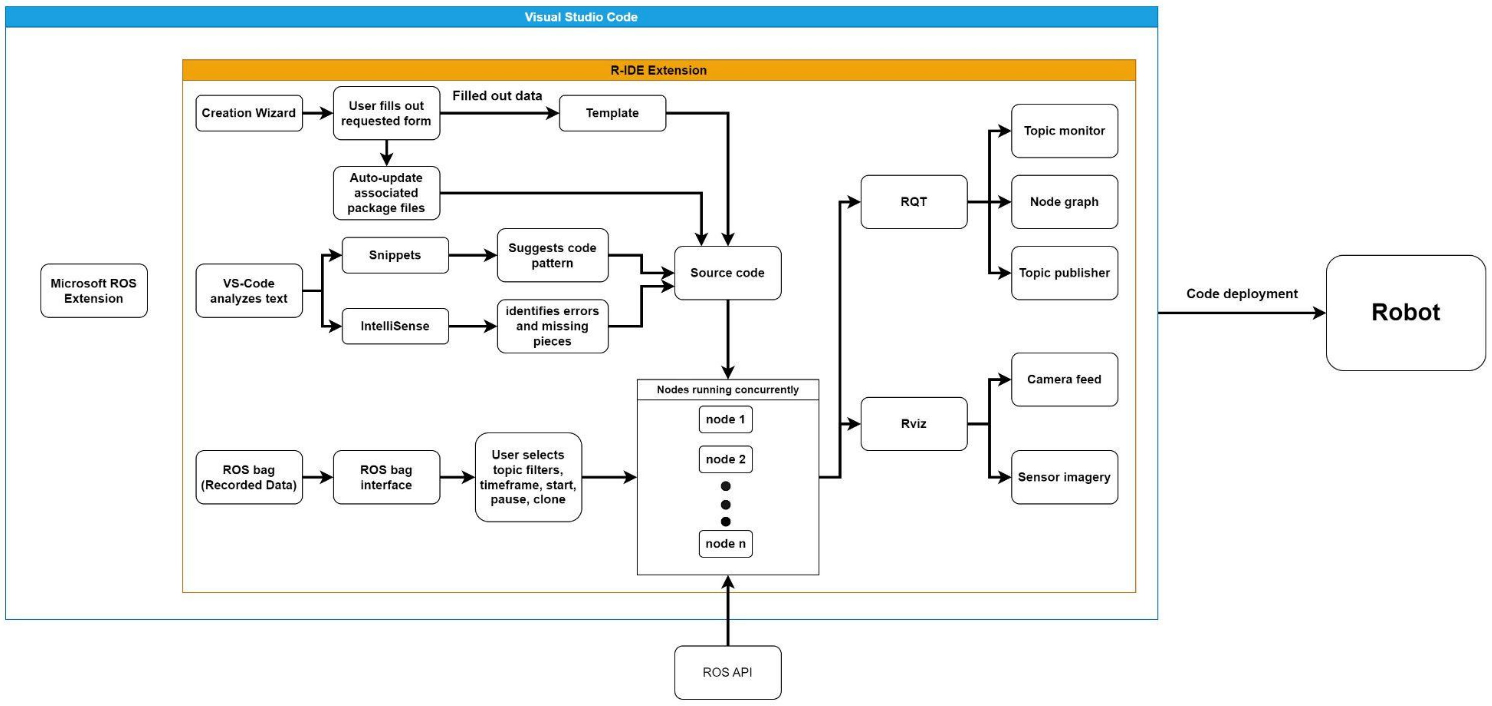
While working with code, developers have access to a variety of tools to speed up development and encourage clean readable, testable code. Users are able to access the various creation wizards to build components of their project, such as creating ROS nodes, topics, and messages. In addition, these wizards make sure to keep the necessary compilation and package files updated as the user makes changes to their source code. While the user is typing, VSCode allows R-IDE to make suggestions to build common code patterns and can implement them for the user.

R-IDE allows users to interact with ROSBags through a separate interface. Users can record, playback, clone, and filter ROSBags entirely with the interface. This allows users to have powerful control over ROSbags without leaving the source code and data stored within the IDE.

A variety of visualization tools inspired by what GUI tools exist are also available to the user. Users can view and publish ROS topics while the ROS master is running while also viewing what nodes are active and connected nodes in the graph view. The major components of R-IDE according to developers are shown in Figure 1.

Figure 1.

Major Functional Component Diagram



3. Identification of Case Study

The main users of R-IDE are ROS developers. ROS developers are often members of the robotics industry, universities, and hobbyists. R-IDE will provide an intuitive interface for ROS development along with the tools to enable new and existing developers.

The purpose of R-IDE is to improve the user experience when developing and interacting with ROS. A case study is being performed at Old Dominion University with members of the Electrical and Computer Engineering department who are currently learning and building with ROS under the direction of Dr. Lee Belfore. Students and professors will use R-IDE within VSCode as their primary development environment. Users will be encouraged to use the templates and wizards in R-IDE to build initial ROS nodes, services, and messages. The developers and maintainers of R-IDE can access usage data so that fixes can be made as quickly as possible and such that it can ascertain how often different services are used and make an estimation of the approximate time to complete a wizard. More data will be collected by providing surveys to the member of the case study and analyzing the time it takes for members to build simple applications.

As more developers migrate to use R-IDE, feedback will improve and expand the capabilities of R-IDE. New services and synergies can be identified that improve upon the development process.

4. R-IDE Product Prototype Description

The purpose of R-IDE is to enable developers to quickly and efficiently build ROS programs. The purpose of this prototype is to build a working solution for the Intelligent Ground Vehicle Competition (IGVC) team to use to build their programs at the competition. R-IDE is designed to be a fully functional VSCode extension at the end of its prototype phase. A working prototype will have proof-of-concept functionalities that range from partial implementation for some visualization tools to a fully working final version for file-handling tools. R-IDE will be able to: assist in creating and updating new ROS nodes, services, and messages; record, play, and edit ROS bags; and manage packages and make files automatically. The development team for

R-IDE will receive feedback directly from Dr. Belfore’s team at weekly meetings and also prompt users for feedback through the extension.

4.1. Prototype Architecture (Hardware/Software)

The prototype architecture will be identical to the real-world product architecture. R-IDE will track how users interact with the different features so as to improve and track what capabilities are most relevant and can be best improved. TypeScript will be the primary language to build the User Interface inside the Svelte frontend framework, while much of the templates will be made up of C++ and Python since ROS is primarily written in these languages. Since the major functional components are the same between the prototype and the working product are identical, Figure 1 illustrates the major components of R-IDE.

R-IDE requires that the user utilizes VSCode as an IDE since R-IDE is hosted on the VSCode Extension Marketplace. The user is required to have a version of ROS relevant to their project along with their own relevant languages for their project. Depending on the version of ROS, the user may be required to have ROS running in a Linux environment (ROS 1) or may be able to also run inside a Windows and Mac environment (ROS 2).

R-IDE inherits its hardware requirements from both VSCode and ROS. RViz and other visualization features are embedded inside the extension, but the requirements for these tools can be dependent on the project the user is working on.

4.2. Prototype Features and Capabilities

Most of the features of R-IDE will be retained in the prototype, however some visualization tools will have only partial implementation. As shown in Table 1, almost all of the features in R-IDE will be included in the prototype. This includes full functionality of the wizards, auto-update, snippets, ROS bags, ROS topics, and the data management tool. The prototype prioritizes the tools that grant the greatest boost in both speed and ease.

Table 1.

R-IDE Real World Product vs Prototype Features

	Feature	RWP	Prototype
Wizard	Create node	Full	Full
	Create msg	Full	Full
	Create srv	Full	Full
Auto update	cmake file	Full	Full
	package.xml	Full	Full
Snippets	Autocomplete Code Patterns	Full	Full
ROS bag	Start Rosbag recording	Full	Full
	Stop Rosbag recording	Full	Full
	Play back Rosbag	Full	Full
Visuals	rviz	Full	Partial: Depending on performance of embedded features
	Node Graph	Full	Full
ROS Topic	ROS topic monitor	Full	Full
	ROS topic publisher	Full	Full
Data Management	Usage Analysis	Full	Full
Test Management	Create Mock Data	Eliminated	Full
Test Management	Automated Tests	Eliminated	Full

While most almost all features will have functionality in the prototype, R-IDE will only have partial functionality for some visulization tools, since they can be articularly expensive to implement inside VSCode and there are tools that exist externally to VSCode. Removing functionality from this feature allows developers to focus on tools that are more efficient and intuitive that do not exist already in another environment for ROS. Doing this allows the team to focus on inventing new tools rather than transferring existing tools to a new environment.

4.3. Prototype Development Challenges

R-IDE is a complex extension that will face many challenges during its development. The primary categories relate to how R-IDE interacts with files and editors, allowing compatibility between different versions of ROS and the languages required, easing the learning curve and leaning less on outdated documentation, and embedding the visualization tools into VSCode.

The earliest challenge to appear in development is tracking and making changes in files, especially as they are edited live. To mitigate this, VSCode offers listener capabilities within its API, allowing extensions to listen on files for changes. After this we can take advantage of regular expressions to identify where in package files to update to match.

Maintaining compatibility between different versions of ROS and the different languages they require is a tedious, but not insurmountable task. The best method is to make parallel changes incrementally, never letting one version or language get too far ahead.

Another potential challenge we face is mitigating the outdated tutorials and documentation. At best, we can simplify our UI, build our own documentation to be clear and consistent, and handle as much in the background as we can. In complicated or difficult situations to predict, we can give the user the ability to override the changes our extension automatically makes.

Visualization tools are a potentially high powered but costly feature to add to R-IDE. While the current prototype only seeks to implement these features partially, we can let the user potentially disable them if they are too costly or ineffective on the user end. Many of these tools already exist as an external tool as a fallback for the user.

5. Glossary

Autonomous Machine: A machine capable of sensing its environment, carrying out computations to make decisions, and performing actions in the real world.

Robot Operating System (ROS): ROS is a set of software libraries that helps to build robot applications. Ranging from drivers to algorithms, and powerful developer tools, ROS is the preferred tool for robotics projects.

ROS Bag: A bag is a file format in ROS for storing ROS message data. These bags have an important role in ROS, and a variety of tools have been written to allow you to store, process, analyze, and visualize them. Bags are the primary mechanism in ROS for data logging, which means that they have a variety of offline uses.

ROS Master: The ROS Master provides naming and registration services to the rest of the nodes in the ROS system. It tracks publishers and subscribers to topics as well as services. The role of the Master is to enable individual ROS nodes to locate one another. Once these nodes have located each other they communicate with each other peer-to-peer. The Master also provides the Parameter Server and is most commonly run using the roscore command, which loads the ROS Master along with other essential components.

ROS Messages: Nodes communicate with each other by publishing messages to topics. A message is a simple data structure, comprising typed fields. Standard primitive types (integer, floating point, boolean, etc.) are supported, as are arrays of primitive types. Messages can include arbitrarily nested structures and arrays. Nodes can also exchange a request and response message as part of a ROS service call.

ROS Node: A node is a process that performs computation. Nodes are combined together and communicate with one another using streaming topics, RPC services, and the Parameter Server.

These nodes are meant to operate at a fine-grained scale; a robot control system will usually comprise many nodes. For example, one node controls a laser range-finder, one Node controls the robot's wheel motors, one node performs localization, one node performs path planning, one node provides a graphical view of the system, and so on.

ROS Parameter Server: A parameter server is a shared, multi-variate dictionary that is accessible via network APIs. Nodes use this server to store and retrieve parameters at runtime. As it is not designed for high performance, it is best used for static, non-binary data such as configuration parameters. It is meant to be globally viewable so that tools can easily inspect the configuration state of the system and modify if necessary.

ROS Services: Request/reply is done via a Service, which is defined by a pair of messages: one for the request and one for the reply. A providing ROS node offers a service under a string name, and a client calls the service by sending the request message and awaiting the reply. Client libraries usually present this interaction to the programmer as if it were a remote procedure call.

ROS Topics: Topics are named buses over which nodes exchange messages. Topics have anonymous publish/subscribe semantics, which decouples the production of information from its consumption. In general, nodes are not aware of who they are communicating with. Instead, nodes that are interested in data subscribe to the relevant topic; nodes that generate data publish to the relevant topic. There can be multiple publishers and subscribers to a topic. Topics are intended for unidirectional, streaming communication. Nodes that need to perform remote procedure calls, i.e. receive a response to a request, should use services instead. There is also the Parameter Server for maintaining small amounts of state.

roswtf: A tool for diagnosing issues with a running ROS system.

rqt: A QT-based framework for GUI development for ROS. It contains tools that support ROS topics, bags, node graphs, and many other tools for visualization and manipulation of ROS nodes

Rviz (Ros Visualization): A 3D visualizer for displaying sensor data and state information from ROS

Template: An editable text or code snippet that can be filled with given values from another tool like a wizard.

Tutorial: A method of transferring knowledge that teach via example and supplies the information to complete a given task.

VSCode Extension: A tool designed to add additional features and capabilities to VSCode. It can create new dialogues, add functions, or change the appearance of VSCode

Wizard: A user interface that presents dialog to lead a user through a sequence of steps. Often used to configure a service for the first time or to simplify a complex or unfamiliar process.

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