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Rockly: A graphical user interface for programming ROS-based robots

MASTER THESIS

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Preamble

<Hier bitte Vorwort schreiben.>
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Abstract

This work presents the development of an graphical user interface for programming ROS-based robots. Robot Operating System (ROS) is a robotics middleware and is considered as the de-facto standard framework for robot software development. The second fundamental framework used for development is Blockly - an open-source JavaScript library made by Google, which provides a visual code editor and a code generation interface for web applications. Programming then is done by simply connecting blocks. Using these frameworks means that the tool can be easily deployed and run on many different platforms. Rockly - the name of the tool and a portmanteau of ROS and Blockly - provides three key components: an interface to manage code blocks, an interface to create demos, and an interface to manage demos. Therefore the presented tool tackles two key points of the field of robotics: teaching robot programming methods and abstracting the complex implementation to a level, where very little technical expertise is required.

Kurzzusammenfassung

Im Rahmen dieser Diplomarbeit wurde eine grafische Benutzeroberfläche entwickelt, mit Hilfe derer ROS-basierte Roboter programmiert werden können. ROS ist eine Middleware und de facto das Standard-Framework in der Entwicklung von Robotik-Software. Das zweite Framework, das dem entwickeltem Tool zugrunde liegt, ist Blockly - eine von Google entwickelte Open-source JavaScript Bibliothek für Web-Applikationen, die eine grafische Programmieroberfläche sowie eine Schnittstelle bereitstellt, mit der aus ebenjener grafischen Oberfläche ein ausführbarer Code generiert werden kann. Ein Programm besteht damit lediglich aus Blöcken, die zusammengefügt werden. Durch die Verwendung dieser beiden Frameworks ist es möglich, dass das entwickelte Tool auf vielen unterschiedlichen Plattformen eingesetzt werden. Rockly - so der Name des Tools, der sich aus den beiden Frameworks ableitet - stellt drei Dienste bereit: eine Oberfläche zum Verwalten der Programmierblöcke, eine Oberfläche zum Erstellen von Programmen und eine Oberfläche zum Verwalten von erstellten Programmen. Aufgrund dieser Eigenschaften bietet das entwickelte Tool Lösungsansätze für zwei aktuelle Diskussions- und Forschungspunkte im Robotikbereich: das Lernen von Roboterprogrammiermethoden und das Abstrahieren der direkten, mittlerweile sehr komplexen Implementierung auf ein Level, das sehr wenig technische Expertise voraussetzt.

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2 Related Work

This chapter examines the related work of fields this work is linked to. It starts with a brief summary of the fundamental development of Visual Programming Languages (VPLs), then presents a classification of them and provides some representative examples. In the next section User Interfaces (UIs) for programming robots are summarized. Then an overview of already existing graphical environments for ROS-based robots is given. Finally, a comparison between matured interfaces with the one presented in this work is presented.

2.1 Visual Programming Languages

There were basically two milestones in the development of a VPL as we know it nowadays. The first milestone was Sketchpad, presented by Ivan Sutherland ([1]). It was designed in 1963 on the TX-2 computer at MIT (Massachusetts Institute of Technology) and has been called the first computer graphics application. The system allowed users to work with a lightpen to create 2D graphics by creating simple primitives, like lines and circles, and then applying operations, such as copy, and constraints on the geometry of the shapes. Its graphical interface and support for user-specifiable constraints stand out as Sketchpad's most important contributions to visual programming languages. By defining appropriate constraints, users could develop structures such as complicated mechanical linkages and then move them about in real time.[2] David Canfield Smith achieved the next major, groundbreaking step in the history of VPLs. In his PhD dissertation [3] he introduced both the use of small pictorial objects, called icons, and the notion of programming by demonstration.

The field of VPLs has grown rapidly in recent years and therefore more and more interest has been focused on creating a robust, standardized classification for work in this area. A lot of frameworks and environments are established in different fields of use, including education, multimedia, video games, simulation and automation processes. Since there are different focus points across these fields, the usage and design variies in a broad spectrum and it is reasonable to classify them. As [2] outlines it is possible to cluster them according to the way users interact with them - e.g. differing *purely visual languages* and *hybrid text*

and visual systems. Another appropiate classification scheme is the following, which focuses more on data- and input processing:

- Block-based languages
- Flowcharts
- Dataflow programming languages

2.1.1 Block-based languages

Block-based VPLs are especially used in tools for reducing barriers for non-programmers or for teaching children programming. The core of these languages is a set of blocks, which can be connected with each other to form an executable program. Each block represents a specific paradigm of the proper programming language. A typical editor consists of a toolbox which contains the code blocks and a workspace, where the blocks can be placed - usually via a drag-and-drop, which is a key feature and make these VPLs considered most intuitive and user-friendly.

The field of application of block-based VPLs covers a wide range: Ardublock[1] is a graphical programming add-on to the default Arduino Integrated Development Environment (IDE) - an open-source electronics platform based on easy-to-use hardware and software, which has a broad community. The MIT App Inventor is a drag-and-drop visual programming tool for designing and building fully functional mobile apps for Android.[4] In the fields of education, Scratch[2], developed in 2007, plays an important role, since it is designed to be highly interactive. The name highlights the idea of tinkering, as it comes from the scratching technique used by hip-hop disc jockeys. In Scratch programming, the activity is similar, mixing graphics, animations, photos, music, and sound. The scripting area in the Scratch interface is intended to be used like a physical desktop (see Figure 2.1)[5].

2.1.2 Flowcharts

These VPLs are able to translate an algorithm's logic given as flowchart into executable machine instructions. According to [6] a flowchart is the graphical representation of a process or the step-by-step solution of a problem, using suitably annotated geometric figures connected by flowlines for the purpose of designing or documenting a process or program. Flowcharts are typically used

[1] http://blog.ardublock.com/
[2] https://scratch.mit.edu/

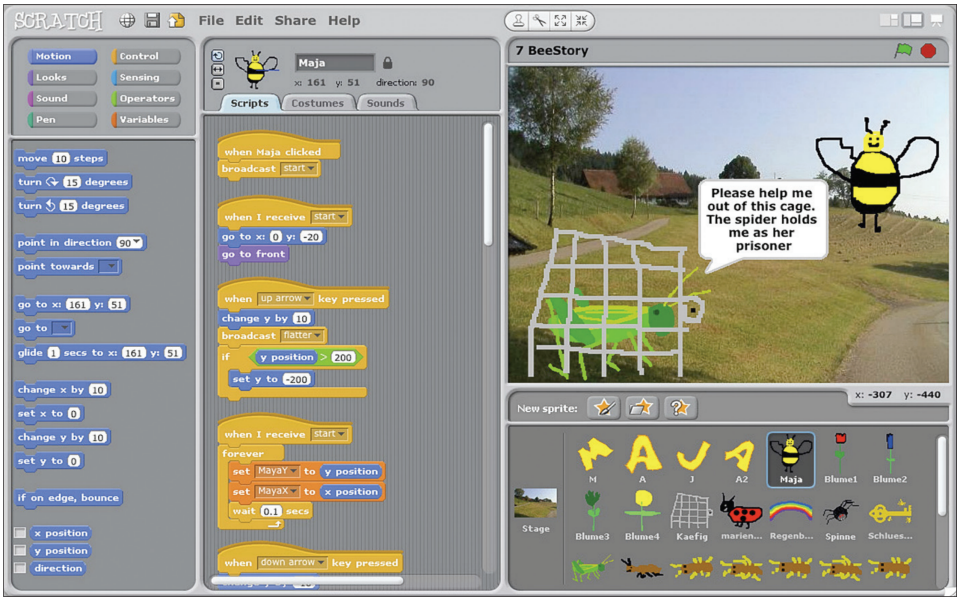


Figure 2.1: Scratch user interface (Source:[5])

in the fields of automation. Grafcet ([7]) is a tool, drawing its inspiration from Petri nets (a general purpose mathematical tool allowing various discrete-event systems to be described), whose aim is the specification of Programmable Logic Controllers (PLCs). It is the basis of the Sequential Function Chart (SFC), an International Standard in 1987. An implementation of the Grafcet norm can be found in S7-GRAPH, developed by Siemens AG and part of their STEP 7 software for programming PLCs (see Figure 2.2).

Another application using a flowchart VPL is KTechLab[4], which is an IDE for microcontrollers and electronics. It supports circuit simulation, program development for microcontrollers and simulating the programmed microcontroller together with its application circuit.

RoboFlow is a flow-based VPL which allows programming of generalizable mobile manipulation tasks [0]. The authors applied a technique called texitProgramming by Demonstration from the field of End-User Programming (EUP) to robot programming. They also presented an implementation on the PR2[5] robot platform using ROS communication.

[3]https://w3.siemens.com/mcms/simatic-controller-software/en/step7/simatic-s7-graph/pages/default.aspx
[4]https://sourceforge.net/projects/ktechlab/
[5]http://www.willowgarage.com/pages/pr2/overview

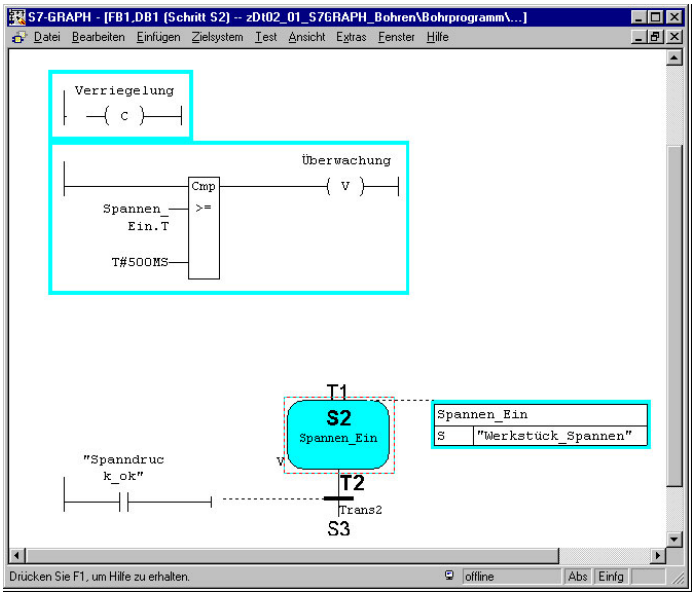


Figure 2.2: S7-GRAPH interface of STEP 7 (Source [3])

2.1.3 Dataflow programming languages

Similar to flowcharts dataflow programming is used for professional applications primarily, aimed at designers rather than end users or coding newbies. Dataflow programming is a programming paradigm whose execution model can be represented by a directed graph, representing the flow of data between nodes, similarly to a dataflow diagram. Considering this comparison, each node is an executable block that has data inputs, performs transformations over it and then forwards it to the next block. A dataflow application is then a composition of processing blocks, with one or more initial source blocks and one or more ending blocks, linked by a directed edge.[8] National Instruments LabVIEW [9] and Simulink (Figure 2.3) can be mentioned as the representatives of this big group.

2.2 Graphical Robot Programming Environments

The driving force of VPLs in terms of graphical programming of robots is education. Teachers rely on simple educational robots and intuitive programming

[6]https://www.mathworks.com/products/simulink.html

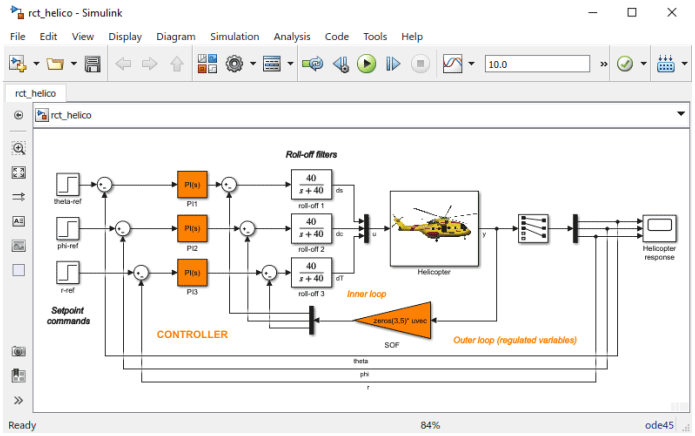


Figure 2.3: User interface of Simulink to use simulation models (Source[6])

environments. Therefore, graphical programming environments have become a frequent starting point for young students. The used environments mostly depends on the robot the corresponding class is programming and therefore there are many offerings.

A famous environment is the *Lego Mindstorms* system[7] - a hardware and software platform for the development of programmable robots based on Lego building bricks. It comes up with an IDE that is available on Windows PC or Mac. Its programming software is based on LabVIEW and provides the ability to downloading programs to the programmable brick, which can be connected to different sensors and actuators. Besides of the default editor the platform also supports the use of third-party environments as outlined in [10].

Dataflow oriented VPLs, like used in the mentioned Lego Mindstorms system, may be not suitable for absolute beginners, as described in [11]. The author mentioned, that the procedural approach where a program is firstly considered as a sequence of statements is much easier to learn than the data flow or functional approach. Therefore a new graphical programming environment, called *Grape*, was developed. With its help a flowchart can be built and the meaning of the individual elements of the flowchart are defined. It comes up with a list of predefined classes for robot programming and provides the feature to extend the list by own classes using a simple Extensible Markup Language (XML) syntax. The code generation itself also uses XML representation: first the graphical structure of the program is converted into a XML tree, which then is translated into C++ code via a mapping schema.

[7]https://www.lego.com/en-us/mindstorms

One of the most powerful graphical robot programming environment is the Open Roberta platform [12]. The connection to the user is called *Open Roberta Lab*, a cloud-based application, which enables children and adolescents to visually program real robot hardware directly from the web browser or by using a build in online robot simulator. It also provides platform features like user login, program saving/sharing and easy hardware pairing over Wi-Fi as well as USB and Bluetooth connection.[13] Its programming language is called *NEPO* and is built up on Google's Blockly, which also plays a fundamental part in this work (see Section 3.2.3 and Section 4.4).

When it comes to humanoid robots, by now, there are three major representatives: Nao[14], Pepper[8] and Romeo[9]. All are developed by SoftBank Robotics and come up with a powerful Software Development Kit (SDK) called *NaoQi*. Besides of SDKs for Python, C++, Java, JavaScript and ROS, the framework also provides a graphical programming tool: Choregraphe[15]. Actually, Choregraphe is a specific module of NaoQi and more or less just a graphical representation of NaoQi's functions. The Choregraphe module produces an XML file describing the program (i.e. the application, the boxes, the connections between them, the included scripts etc.). For execution, the file is interpreted by the XML module of NaoQi. Since the architecture of humanoid robots is very complex, even experienced programmers, at least partly, rely on interfaces like Choregraphe and therefore it is not exclusively used for education.

Another hybrid robot programming environment is provided by Aseba Studio[10] IDE of the Thymio II, a small and low-priced educational robot. It provides pure visual programming, two block based VPLs (Scratch, Blockly) as well as an editor and an Application Programming Interface (API) for text programming. It is also possible to connect the robot and directly run and debug the program via the user interface.

2.3 Environments for ROS-based robots

As stated in the beginning, ROS is considered as the de-facto standard framework for robot software development. Nonetheless the environments explained in Section 2.2, as well as other frameworks too, do not provide ROS connectivity out-of-the-box.

[8] https://www.softbankrobotics.com/emea/en/pepper
[9] https://projetromeo.com/
[10] https://www.thymio.org/en:asebastudio

This might be reasonable when thinking of purchasing a robot is not cheap. If an user needs to control just one robot, there is no necessity to search for a generic tool - especially because such a tool most likley would not provide as powerful capabilities as the default programming interface would do. Assuming the case of a lab, where several people might working with different robots or just quick showcases are desired, it is reasonable to design such an interface. Right now, there a only a few frameworks available for such purposes.

Erle Robotics developed a web-based visualization and block programming tool, called *robot_blockly*, which supports their own robots and drones [16]. It comes pre-installed with their Linux-based artificial robotic brain *Erle-Brain*[11] and also provides a rudimentary interface for all other robots. It uses the standard block creation process of Blockly (Section 3.2.3). Therefore the user needs to update different files of the source code, must follow some naming rules, recompile Blockly and the package and also needs - apart from ROS - basic JavaScript knowledge. The ROS connectivity and all execution routines can be implemented in a Python file, which is read from a specific directory and then included into the Blockly source code.

Another Blockly-based tool for controlling ROS-based robots is the *evablockly_ros* package, developed by Inovasyon Muhendislik[17]. The provided blocks are mainly created specifically for operations that can be performed by using evarobot, a mobile robot platform built by the author. Apart from them the package also provides the following basic ROS connectivity features:

- set up server connection
- create a publisher to send data
- send data via created publisher
- create a subscriber to receive data
- perform operations when data is received from determined subscriber

2.4 Comparison of visual programming tools

This section provides a comparison of this work with some visual programming tools presented in the previous sections in respect of their features. The following systems were considered: robot_blockly[18], Choregraphe[15], Open

[11] http://docs.erlerobotics.com/brains/erle-brain-3

Roberta Lab[13], Grape[11] and EV3[19]. The specified features target two important fields of the tool decision process - platform independency and usablity. Those two main features are broken down to several minor criteria, as Table 2.1 shows. All of the mentioned tools come with an IDE for multiple computer platforms and operation systems.

Most of the tools provide a block-based programming interface, which tends to be the simplest VPL type in terms of usablity. Conclusively, the two most popular educational programming platforms, EV3 - the newest generation of the Lego Mindstorms system - Open Roberta Lab, are included. Since EV3 also provides the ability to use third-party environments, all VPLs are supported as well as pure coding itself. When looking at the provided programming options of Choregraphe, it is highlighted that it is possible to create complex programms with it, but getting there requires more technical expertise. The tool presented in this work, Rockly, trys to reach both audiences.

Open Roberta Lab supports seven different robot platforms out of the box, which is significantly more than the other tools. Besides its own programming brick, EV3 supports its preceding robot system NXT partially at the moment, but allows the integration of third-party sensors and motors. Choregraphe Suite supports platforms providing the NaoQi SDK, which are currently three physical robots. All other tools only provide connectivity to one robot though, but are able to be upgraded via different interfaces. Only Rockly comes up with an assistant, the others require to touch or recompile the source code.

Besides the number of robots, which can be connected to a system, platform independency also means, that different operating systems are supported. Web-based applications are the most independent ones, since users are not required to install software on their computers. Running the infrastructure on a server allows users to connect to the robot remotely and use it on mobile devices too. EV3 currently supports mobile devices with the following minimum versions: Android 4.2, iOS 8.0. Of the evaluated tools Rockly, robot_blockly and Open Roberta Lab are fully web-based. All of them are based on Google's Blockly framework.

Development support interfaces such as a robot simulator and a debugging tool are only provided by three tools. When comparing this to the programming types, a pattern could be obtained. One of the advantages using a block-based VPL is that the translated code is always syntactically correct, so a major reason using such support during development, is obsolete.

When it comes to ROS connectivity the classification outlined in Section 2.2 and Section 2.3 can be applied. It is possible to create ROS nodes with each tool - except EV3. It is worth a remark that Choregraphe's NaoQi SDK provides ROS connectivity only via code represention, i.e. it is not possible to use ROS communication within the graphical programming interface. Of the tools enabling updates for both ROS connectivity and robot platforms, all provide a manual, but only the workflow of Rockly is tool assisted. This means that upgrading is more of a configuration than programming process - depending on how complex the desired block should be. Therefore less programming knowledge is required - especially in terms of the communication patterns of ROS. Not touching the source code also means no recompiling, which therefore leads to the fact, that - once deployed - Rockly runs autonomously without any internet connection required.

Feature		Rockly	robot_blockly	Choregraphe	Open Roberta Lab	Grape	EV3
Programming	block-based	✓	✓		✓		✓
	flowchart					✓	✓
	dataflow			✓			✓
	code	✓		✓			✓
Robot platforms	out-of-the-box	1	1	1	7	1	2[a]
	upgradeable	✓	✓		✓	✓	
User interface	upgrade assistant	✓					
	web-based	✓	✓		✓		
	simulator			✓	✓		
	debugging			✓			✓
ROS connectivity	out-of-the-box	✓	✓				
	upgradeable			(✓)[b]	✓	✓	
Upgrade workflow	tool assisted	✓		-			-
	manual	✓	✓	-	✓	✓	-
	programming languages	1	2	-	2	2	-
	recompiling		✓	-	✓		-

Table 2.1: Comparison of visual programming platforms

[a] third-party sensors and motors are supported
[b] not for visual programming environment

3 Architecture

This chapter describes the architectural design of Rockly (portmanteau of ROS and Blockly). First the requirements are presented, then the purpose and need of the tool are explained. Based on this constraints the options implemtenting the tool are presented as well as an explanation of the final design. Then an overview of the architecture is given, followed by a short description of all supporting frameworks and dependencies, which are: the robot operating system ROS with its concepts and some JavaScript frameworks, which eased the implementation effort.

3.1 Requirements

In the field of software engineering constraints are the basic design parameters. Therefore, it is necessary to provide them as detailed as possible. In the given case the basic constraints are given by the purpose of the tool and the architecture of the robot.

3.1.1 HOBBIT - The Mutual Care Robot

The HOBBIT PT2 (prototype 2) platform was developed within the EU project of the same name. The robot was developed to enable independent living for older adults in their own homes instead of a care facility. The main focus is on fall prevention and detection. PT2 is based on a mobile platform provided by Metralabs. It has an arm to enable picking up objects and learning objects. The head, developed by Blue Danube Robotics, combines the sensor set-up for detecting objects, gestures, and obstacles during navigation. Moreover, the head serves as emotional display and attention center for the user. Human-robot interaction with Hobbit can be done via three input modalities: Speech, gesture and a touchscreen. [20]

In terms of technology HOBBIT (see Figure 3.1) is based on the robot operating system ROS (Section 3.4.1), which allows easy communication between all components. The system is set up to be used on Ubuntu 16.04 together with the ROS distribution *Kinetic*. All ROS nodes are implemented in either

Figure 3.1: HOBBIT - The Mutual Care Robot

Name	Type	Message type	Description
/cmd_vel	Topic	geometry_msgs/Twist	move HOBBIT
/head/move	Topic	std_msgs/String	move HOBBIT's head
/head/emo	Topic	std_msgs/String	control HOBBIT's eyes
/MMUI	Service	hobbit_msgs/Request	control UI interface
hobbit_arm	Action	hobbit_msgs/ArmServer	control HOBBIT's arm
move_base_simple	Action	geometry_msgs/PoseStamped	navigate HOBBIT

Table 3.1: Common commands used by HOBBIT

Python or C++. In order to provide a fast and simple way to implement new behaviours several commands should be pre-implemented. These commands are performed either by publishing messages to topics or services, or executing callbacks defined in the corresponding action's client. The common commands and their description are listed in Table 3.1. A detailed list of possible messages for each command is presented in Chapter D.

3.1.2 Purpose of the tool

HOBBIT became very popular since the above mentioned EU project and demos of it's behaviours have been presented at a large number of fairs. Unfortunally only the following show cases are currently implemented on the robot:

- HOBBIT follows the user
- HOBBIT learns object
- HOBBIT starts an emergency call
- HOBBIT picks up an object

All of the demos can be started via the user interface running on HOBBIT's tablet, but re-writing new demos would assume a detailed knowledge of the robot's setup. In order to implement new behaviours and demos more easily it is necessary to provide a programming interface, which provides a powerful, generic base to cover a wide range of HOBBIT's features as well as an intuitive handling.

Furthermore the Automation and Control Institute of the TU Wien is part of the Educational Robotics for STEM (ER4STEM) project, which aims to turn curious young children into young adults passionate about science and technology with hands-on workshops on robotics. The ER4STEM framework will coherently offer students aged 7 to 18 as well as their educators different perspectives and approaches to find their interests and strengths in robotics to pursue STEM careers through robotics and semi-autonomous smart devices. [21] Providing an intuitive programming tool would allow the integration of HOBBIT into the project, which would be an extra input evaluation parameter.

Finally, the framework should be implemented to be re-used for other ROS based robots. This means that it should not only provide an interface to the mentioned commands for HOBBIT, but an open, adpatable framework. It should be able to allow a flexible configuration and assembly of the provided functions.

3.2 Options

There are several approaches to fulfill the mentioned requirements. In the following subsections three different options are presented by a simple example: the implementation of picking up an object from the floor and putting it on the table. This should give a rough overview in terms of complexity of the usability as well as the implementation of the corresponding approach. For reasons of simplicity tasks like searching and detecting the object or gripper positioning are excluded.

3.2.1 Custom API

The most obvious way to fulfill the requirements is to provide an API for the desired programming languages (Python, C++). An API is a set of commands, functions, protocols and objects that programmers can use to create software or interact with an external system. It provides developers with standard commands for performing common operations so they do not have to write the code from scratch. In the present case such an API could consists of the following components:

- Initialization: setting up communication and intial states - e.g. creating ROS nodes, starting the arm referencing or undocking from charger
- Topic management: managing the messages published to ROS topics and creating subscriber nodes if applicable
- Service management: managing the ROS services of HOBBIT - e.g. the tablet user interface
- Action management: creating ROS action clients for e.g. navigation or arm movement
- Common commands: providing common commands (see Table 3.1)

It should be noted that the components do not re-implement ROS functionality, but extend it and prvovide a simpler use of it. Depending on how generically the API is implemented it is possible that the user can control the robot without any detailed knowledge of the technical setup. Nevertheless, this approach would assume the user to have knowledge of the programming language the API is desigend for. Refering to the required commands in Table 3.1 an API for Python could be designed as shown in Figure 3.2. The highest usability would be reached, if all input parameters are from common variable types such as interger and string. Indeed, this would increase the implementation effort, especially in terms of error handling, as well as the extent of the documentation, which are huge disadvantages of writing an API.

Assuming the API would be implemented as explained before and the Python module would be named *HobbitRosModule*, Listing 3.1 shows a sample code for the mentioned use case to pick up an object. Note that the code is very short and easy to read, which - on the other hand - means that the implementation of the API must cover a broad technical range, such as error handling for unsupported inputs and communication errors.

Figure 3.2: Exemplary design of an API for Python

```
1 import HobbitRosModule  # Import of API module
2
3 node = HobbitRosModule.node('demo') # Create ROS node
4 node.gripper('open')    # Open gripper
5 node.move_arm('floor')  # Move arm to floor pick up
     position
6 node.gripper('close')   # Close gripper = pick object
7 node.move_arm('table')  # Move to table position
8 node.gripper('open')    # Open gripper = drop object
```

Listing 3.1: Example Python code using the API shown in Figure 3.2

3.2.2 SMACH

SMACH is a task-level architecture for rapidly creating complex robot behavior. At its core, SMACH is a ROS-independent Python library to build hierarchical state machines. [22]. Since that, this approach would also end up in providing an API for the user, but allows to create more complex demos with less effort than the one described in Section 3.2.1. SMACH also provides a powerful graphical viewer to visualize and introspect state machines as well as an integration with ROS, of course. Since the aforementioned example is a very simple one and does not require a lot of the provided SMACH functionality, this section only covers the needed ones to fulfill the requirements. For a detailed description on how to use SMACH refer to [22].

The arm of HOBBIT is controlled via the hobbit_arm action. SMACH supports calling ROS action interfaces with it's so called *SimpleActionState*, a state class that acts as a proxy to an *actionlib* (see Section 3.4.1) action. The instantiation of the state takes a topic name, action type, and some policy for generating a goal. When a state finishes, it returns a so called *outcome* - a string that describes how the state finishes. The transition to the next state will be specified based on the outcome of the previous state. Listing 3.2 shows a possible implementation of picking up a object an placing it on the table. After the imports of the necessary modules (lines 1 to 4), the state machine is instanced (line 7), to which the required states are added (lines 17-22). The parameters passed to *SimpleActionState* are

- the name of the action as it will be broadcasted over ROS (e.g. *hobbit_arm*)
- the type of action to which the client will connect (e.g. *ArmServerAction*) and
- the goal message.

For reasons of readability the goals are declared at a seperate code block (lines 11 to 14). The equivalent visualization of the state machine is shown in Figure 3.3.

Providing just the SMACH interface has some disadvantages and would not be practicable. First, the user would need an advanced knowledge of Python. Depending on the design of the self-implemented API (Section 3.2.1) the knowledge has to be at least at the same level. Next the user would have to understand the API and needs to find a design to fit for the corresponding

```
1  from smach import StateMachine
2  from smach_ros import SimpleActionState
3  from hobbit_msgs.msg import ArmServerGoal,
       ArmServerAction
4  from rospy import loginfo
5
6  # Instance of SMACH state machine
7  sm = StateMachine(['finished','aborted','preempted'])
8
9  with sm:
10     # Definition of action goals
11     goal_floor = ArmServerGoal(data='
           MoveToPreGraspFloor', velocity=0.0, joints=[])
12     goal_table = ArmServerGoal(data='
           MoveToPreGraspTable', velocity=0.0, joints=[])
13     goal_OpGrip = ArmServerGoal(data='OpenGripper',
           velocity=0.0, joints=[])
14     goal_ClGrip = ArmServerGoal(data='CloseGripper',
           velocity=0.0, joints=[])
15
16     # Assambly of the full state machine
17     StateMachine.add('INITIAL_POS', SimpleActionState('
           hobbit_arm',ArmServerAction,goal=goal_OpGrip),
           transitions={'succeeded':'FLOOR_POS','aborted':'
           LOG_ABORT', 'preempted':'LOG_ABORT'})
18     StateMachine.add('FLOOR_POS', SimpleActionState('
           hobbit_arm',ArmServerAction,goal=goal_floor),
           transitions={'succeeded':'CLOSE_GRIPPER','
           aborted':'LOG_ABORT', 'preempted':'LOG_ABORT'})
19     StateMachine.add('GRIPPER_CLOSED',
           SimpleActionState('hobbit_arm',ArmServerAction,
           goal=goal_ClGrip),transitions={'succeeded':'
           TABLE_POS','aborted':'LOG_ABORT', 'preempted':'
           LOG_ABORT'})
20     StateMachine.add('TABLE_POS', SimpleActionState('
           hobbit_arm',ArmServerAction,goal=goal_table),
           transitions={'succeeded':'OPEN_GRIPPER','aborted
           ':'LOG_ABORT', 'preempted':'LOG_ABORT'})
21     StateMachine.add('GRIPPER_OPEN', SimpleActionState(
           'hobbit_arm',ArmServerAction,goal=goal_OpGrip),
           transitions={'succeeded':'finished','aborted':'
           LOG_ABORT', 'preempted':'LOG_ABORT'})
22     StateMachine.add('LOG_ABORT', loginfo('Demo aborted
           !'), transitions={'succeeded': 'aborted'})
```

Listing 3.2: Using SMACH to generate a state machine

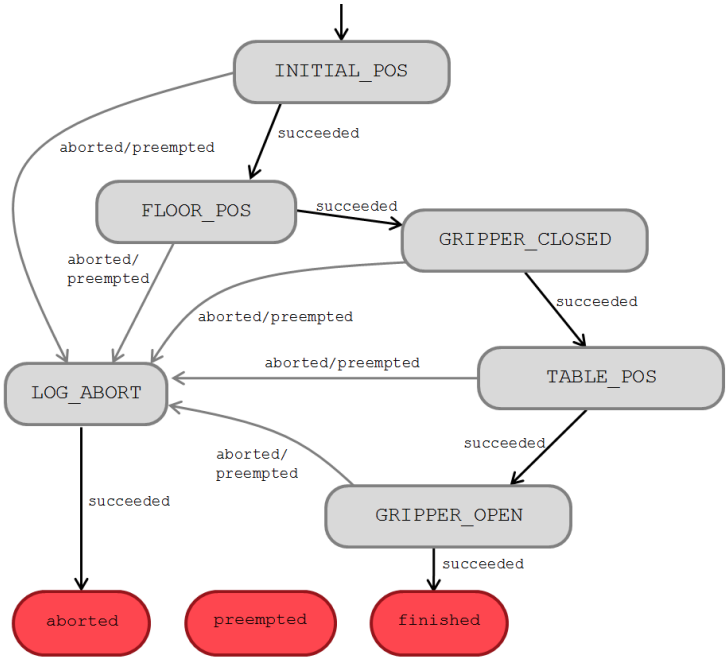


Figure 3.3: State machine generated via Listing 3.2

demo case. Furthermore, it requires the user also to exactly know the ROS specification of the robot. So, if SMACH would be choosen as the underlying framework, it would also be necessary to provide a more abstract API - basically with the same interfaces as shown in Figure 3.2.

3.2.3 Blockly

Blockly is a library that adds a visual code editor to web and Android apps. The Blockly editor uses interlocking, graphical blocks to represent code concepts like variables logical expressions, loops, and more. It allows users to apply programming principles without having to worry about syntax or the intimidation of a blinking cursor on the command line. [23] So for the present case, in contrast to the other approaches the user would not need to have any technical knowledge of HOBBIT, its components and interfaces. Furthermore, such an editor would not require the user to master any programming language. On the other hand implementing this approach would require additional knowledge of web applications (i.e. JavaScript, HTML and CSS).

Figure 3.4 shows an exemplary injection and use as well as the basic structure of Blockly applications. It consists of a toolbox, from where the progamming

Figure 3.4: A short Blockly demo showing it's structure and use

blocks can be dragged to the workspace where they are connected. The Blockly API [24] provides a function to generate a code for all blocks in the workspace to several languages: JavaScript, Python, PHP, Lua, Dart and XML. In the shown example for each of them a tab is avaible to show the generated code. The blocks dragged to the workspace in Figure 3.4 are already customized blocks, with whom an object can be picked up and be placed on the table. There are basically four steps requierd in order to create and use a custom block, which are briefly described in the following paragraphs. A detailed documentation is given in [25].

Defining the block

Blocks are defined in the `/blocks/` directory of the source code by adding either JSON objects or JavaScript functions to the `Blockly.Blocks` mapping. It includes the specification of the shape, fields, tooltip and connection points. An exampe definition using a JavaScript function of the *gripper* block is shown in Listing 3.3. Attention should be payed to lines 6 to 21, where the input fields are defined (line 8). Here a dropdown field with two options ("Open" and "Close") is created. The name ("gripper_position") is used to refer to it later.

Providing the code

Similar to the definition of a block, the code, which is generated out of them, is stored in a mapping variable inside the Blockly library. Since different languages are supported, the code definition has to be in the right directory. Note that it is not necessary to provide code for each language. The code generation is handled in the `/generator/` directory of the library. Each language has it's own

```
Blockly.Blocks['hobbit_arm_gripper'] = {
    init: function () {
        this.jsonInit({
            "type": "hobbit_arm_gripper",
            "message0": "%1 Gripper",
            "args0": [
                {
                    "type": "field_dropdown",
                    "name": "gripper_position",
                    "options": [
                        [
                            "Open",
                            "open"
                        ],
                        [
                            "Close",
                            "close"
                        ]
                    ]
                }
            ],
            "previousStatement": null,
            "nextStatement": null,
            "colour": 360,
            "tooltip": "Control HOBBIT's gripper",
            "helpUrl": ""
        });
    }
};
```

Listing 3.3: Block initialization using a JavaScript function

helper functions file (e.g. `python.js`) and subdirectory, where the code for each block is defined. There are several interfaces functions provided by Blockly to manage interaction with a block - such as collecting arguments of the block. A short example to control HOBBIT's gripper is shown Listing 3.4. In line 2 the `block.getFieldValue()` function is used to get the user's selection of the dropdown field. Note that the generator always returns a string variable including the code in the desired language (line 4). So the shown example requires to use a custom Python API (such as Figure 3.2), because `node.gripper()` is not a built-in function of Python.

```
1 Blockly.Python['hobbit_arm_gripper'] = function(block)
    {
2   var dropdown_movement = block.getFieldValue('
      gripper_position');
3
4   return 'node.gripper(\''+dropdown_movement+'\')\n';
5 };
```

Listing 3.4: Defintion of a code generator in Blockly for Python

Building

After the customized block and it's code generator are defined, the whole Blockly project has to be rebuilt by running `python build.py`. Building means that the source code, which is usually spread to several files (in the given case over a hundred), is converted into a stand-alone form, which can be easily integrated. The Blockly build process uses Google's online Closure Compile and outputs compressed JavaScript files for core functionalites, blocks, block generators for each progamming language and a folder including JavaScript files for messages in several lingual languages. In our case the following four files needs to be included:

- `blockly_compressed.js`: Blockly core functionalites
- `blocks_compressed.js`: Defintion of all blocks
- `python_compressed.js`: Code generators for all blocks
- `/msg/js/en.js`: English messages for e.g. tooltips

Add it to the toolbox

Once the building is completed and the necessary files are included to the web application, the custom block needs to be included in the toolbox. The toolbox is specified in XML and passed to Blockly when it is injected. Assuming the blocks shown in Figure 3.4 are build as described in the previous paragraphs, they can be add to the toolbox as shwon in Listing 3.5.

```
1 <xml id="toolbox" style="display: none">
2   <block type="hobbit_arm_gripper"></block>
3   <block type="hobbit_arm_movement"></block>
4 </xml>
```

Listing 3.5: Minimal example of adding two blocks to a Blockly toolbox

3.2.4 Decision

In order to select the best fitting solution the requirements explained in Section 3.1 are summarized as follows:

- The user wants to build as complex demos as possible.
- The user wants an intuitive interface to create demos.
- The user should need as little knowledge of the robot as possible.
- The user should need as little technical knowledge as possible.
- The implementation of the tool should not exceed the usual effort of a master thesis.
- The tool should provide the ability to add new functionalites.
- The tool should be maintable, meaning it should have clear interfaces and as less dependencies as possible.

The selection is based on rating each of the approaches in regards of each single requirement mentioned with a score ranging from 0 (lowest) to 5 (highest). The approach with the highest overall score is seen as the best fitting one and will be implemented. Table 3.2 shows the result of the evaluation. Based on the assessment Blockly convinced with its very intuitive interface, which requires the user to have very little previous knowledge to build demos. Despite the

fact that maintainability and scalability suffer from the high abstraction and encapsulation of the libary, the effort in terms of implementation is not worth mentioning compared to the other approaches. This results from the fact that each one would require the design of a custom API. Instead of just abstracting the given ROS functionality, Blockly adds a much more user-friendly option to create demos - in contrast to the others.

	Custom API	SMACH	Blockly
Complexity of demos	3	4	2
User Interface	2	2	5
Robot specific know-how	3	1	5
Technical know-how	1	1	5
Implementation	2	3	3
Scalability	4	3	2
Maintainability	3	3	1
Σ	18	17	23

Table 3.2: Evaluation of possible approaches

3.3 Design

Based on the mentioned framework decision a design for the tool was developed. Figure 3.5 gives an overview of Rockly's final architecture and it's components. While the frontend consists of the following five components:

- a **Demo Management** which allows the user to create, edit, delete and run demos easily,
- a **Code Editor** to allow further editing of the generate code before running it on the robot,
- the **Code Generation** with the help of Blockly - the heart of the tool,
- an interface for creating and managing custom blocks (**Block Configuration**, which then can be used for code generation,
- sending and receiving data from the robot via the **Backend Communication**

the backend is made up of the following four:

- sending and receiving data from the user interface via the **Frontend Communication**,
- a **Storage Management**, which provides the demos and custom blocks to the user,
- a **Python Module** containing all necessary functionalites to provide an ROS executable code,
- an interface to finally execute the generated code on the robot (**Code Execution**).

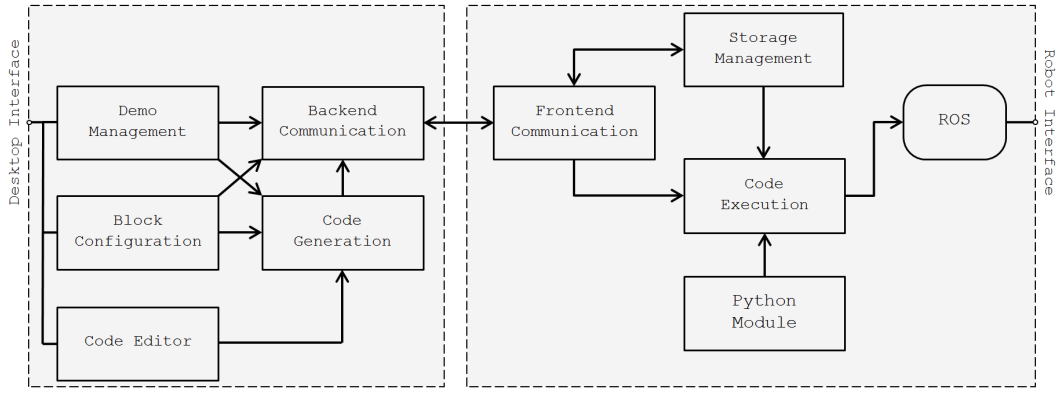


Figure 3.5: Frontend and backend architecture

3.4 Supporting frameworks & dependencies

As described the components can be clustered into frontend and backend, but they can be seen also in respect of their functional interfaces. On the one hand there is a connection to the robots sensors and actuators, on the other hand there is an interface to the human using the tool. Both functionalites are build up with the support of software frameworks, which are described in the following sections.

3.4.1 ROS

ROS provides libraries and tools to help software developers create robot applications. It provides hardware abstraction, device drivers, libraries, visualizers, message-passing, package management, and more. Since ROS is licensed under

an open source, BSD license it used for a wide range of robots, sensors and motors. Covering all of its features would go beyond the scope of this thesis, so just the concepts, which are needed to implement Rockly, are summarized. [26]

Packages

Software in ROS is organized in packages. A package might contain ROS nodes, a ROS-independent library, a dataset, configuration files, a third-party piece of software, or anything else that logically constitutes a useful module. The goal of these packages is to provide this useful functionality in an easy-to-consume manner so that software can be easily reused.

Nodes

A node is a process that performs computation and are written with the use of a ROS client library, such as roscpp (for C++) or rospy (for Python). Nodes are combined together into a graph and communicate with one another using streaming topics, RPC (Remote Procedure Call) services, and the Parameter Server. 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, and so on.

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. Each topic is strongly typed by the ROS message type used to publish to it and nodes can only receive messages with a matching type.

Messages

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. Message descriptions are stored in .msg files in the `/msg/` subdirectory of a ROS package.

Services

The publish-subscribe model is a very flexible communication paradigm, but its many-to-many one-way transport is not appropriate for RPC request-reply interactions, which are often required in a distributed system. Request-reply in ROS is done via a service, which is defined by a pair of messages: one for the request and one for the reply. Services are defined using .srv files, which are compiled into source code by a ROS client library.

Actions

In some cases, e.g. if a service takes a long time to execute, the user might want the ability to cancel the request during execution or get periodic feedback about how the request is progressing. The actionlib package provides tools to create servers that execute long-running goals that can be preempted. It also provides a client interface in order to send requests to the server. The action client and action server communicate via the ROS Actionlib Protocol[1], which is built on top of ROS messages. The client and server then provide a simple API for users to request goals (on the client side) or to execute goals (on the server side) via function calls and callbacks.

3.4.2 JavaScript frameworks

Since Rockly is a web application all of the functionality blocks do touch JavaScript in some way. And since there are a lot of JavaScript frameworks supporting the development of web applications, it is necessary to get an overview of the important ones - besides Blockly (see Section 3.2.3) - used to implement Rockly before diving into the implementation itself.

Node.js

Node.js is an open source platform that allows you to build fast and scalable network applications using JavaScript. Node.js is built on top of V8, a modern JavaScript virtual machine that powers Google's Chrome web browser. At its core, one of the most powerful features of Node.js is that it is event-driven. This means that almost all the code written in Node.js is going to be written in a way that is either responding to an event or is itself firing an event (which in turn will fire other code listening for that event). In an effort to make the code as modular and reusable as possible, Node.JS uses a module system - called

[1] http://wiki.ros.org/actionlib

"Node Package Manager" (NPM) - that allows to better organize the code and makes it easy to use third-party open source modules.

Express

Express is a minimal and flexible Node.js web application framework, providing a robust set of features for building single, multi-page, and hybrid web applications. In other words, it provides all the tools and basic building blocks one need to get a web server up and running by writing very little code. Listing 3.6 shows a minimal example of using Node.js and Express to implement the famous "Hello World" program. First the Express module is imported (Line 1) and an instance of the app is created (Line 2), which finally listens to the configured port (Line 6). Line 3 to 5 describes the mentioned event-driven behavior: `app.get('/',...)` causes every request to trigger the given callback function, which in this case is just sending the "Hello World" string.

```
1 var express = require('express');
2 var app = express();
3 app.get('/', function(req, res){
4    res.send('Hello World');
5 });
6 app.listen(3000);
```

Listing 3.6: "Hello World" program implemented using Node.js and Express

Ace

Ace, whose name is derived from "Ajax.org Cloud9 Editor", is a standalone code editor written in JavaScript. Ace is developed as the primary editor for Cloud9 ide) - an online integrated development environment - and the successor of the Mozilla Skywriter (formerly Bespin) Project. It supports syntax highlighting and auto formatting of the code as well as customizable keyboard shortcuts.

jQuery

jQuery is a fast, small, and feature-rich JavaScript library. It makes things like HTML document traversal and manipulation, event handling, animation and ajax (Asynchronous JavaScript and XML) much simpler with an easy-to-use API that works across a multitude of browsers. Rockly basically uses its functionality to exchange data via RESTful (Representational State Transfer) web services and manipulating HTML elements.

4 Implementation

This chapter gives detailed insights into the implementation of Rockly. Each component presented in the architectural overview (Section 3.3) is explained together with the essential code snippets.

4.1 Backend & Frontend Communication

The communication between frontend (client) and backend (server) is done via a RESTful API. A RESTful API is based on representational state transfer (REST) technology and uses HTTP (Hypertext Transfer Protocol) request methods, which are defined in RFC 2616 [27], to exchange data between web services. All implemented API endpoints, which are used to manage demos and codes are listed in Table 4.1.

Type	Path	Description
GET	/demo/list	list all demos saved on the robot
GET	/demo/load/*{demoId}*	get the XML tree of a demo
POST	/demo/save	save a new demo on the robot
POST	/demo/run/*{demoId}*	run a demo
DELETE	/demo/delete*{demoId}*	delete a demo
GET	/demo/toolbox	load the toolbox of the Blockly interface
GET	/block/list	list all already configured custom blocks
POST	/block/create	create a new custom block
PUT	/block/update/*{blockId}*	update a custom block
DELETE	/block/delete/*{blockId}*	delete a custom block

Table 4.1: API endpoints for managing demos and custom blocks

4.2 Demo Management

The Demo Management (Figure 4.1) is one key feature of Rockly and the entry point of it. It gives an overview of all avaible demos, meaning demos, which

are saved on the robot in a specific directory. It provides a graphical interface and hence makes it a lot easier to manage and run demos - in contrast to the other mentioned options (Section 3.2), where e.g. the user needs to explicity locate the file and run it. Since usability and simplicity are main requirements for this tool, such a feature is a main advantage of it. Furthermore the main page provides the option to create new demos and a redirection to the block configuration component (Section 4.3).

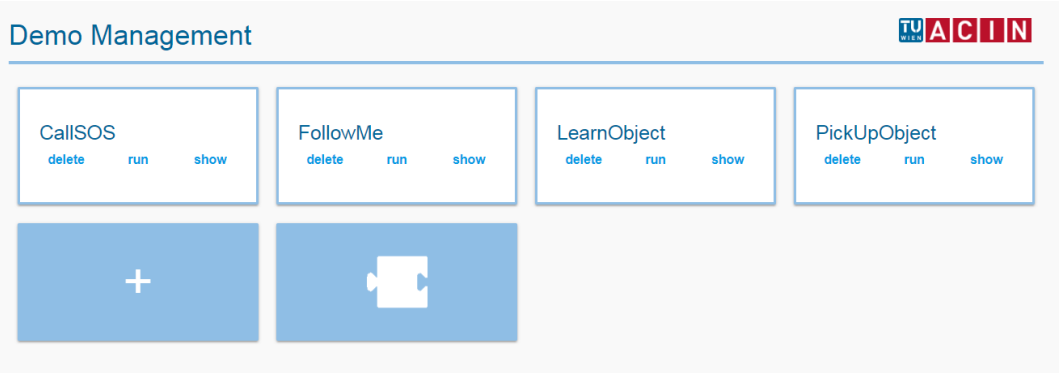


Figure 4.1: Demo Management Page

At the start of the tool the `/demos/` directory inside the tools folder on the robot is searched for saved demos. Since we talking about a web-based tool and demos are saved on the robot, this requieres a call to the backend, which then returns a list of all demos via the RESTful API. The structure of all demos are stored in `.xml` files, which are interpreted by Blockly.

4.3 Block Configuration

There are a lot of reasons a user want to create a custom block. The pre-implemented blocks are designed for the ROS architecture of HOBBIT and any other robot won't show the desired behavior when receiving commands sent from these blocks. Even for HOBBIT itself the provided block set does not cover all of its functionalites. Using another robot means publishing different data to other topics, calling other services and using other action clients. Of course, the user can walk through the whole custom block creation process described in Section 3.2.3 to create new blocks. This requieres knowledge of progamming in JavaScript and the Blockly API. The user would then be able to use all of Blockly's broad range of features and advantages, especially dynamically changing of block features.

On the other hand, for a lot of the tasks such features are not necessary or a workaround with less effort can be found, respectively. For this reason Rockly provides a block configuration interface, which allows the user to create custom blocks with the two basic visual designs: an execution block and an input block (Figure 4.2). With this interface the user can configure blocks for publishing data to topics, calling services with parameters and creating simple action clients.

Figure 4.2: Basic visual designs: execution block (left) and input block (right)

The design of the interface is shown in Figure 4.3. It is devided into three sections:

I. An overview of already created custom blocks

II. A form to provide general information of the block

III. A form to provide detail information of the block (type-specific)

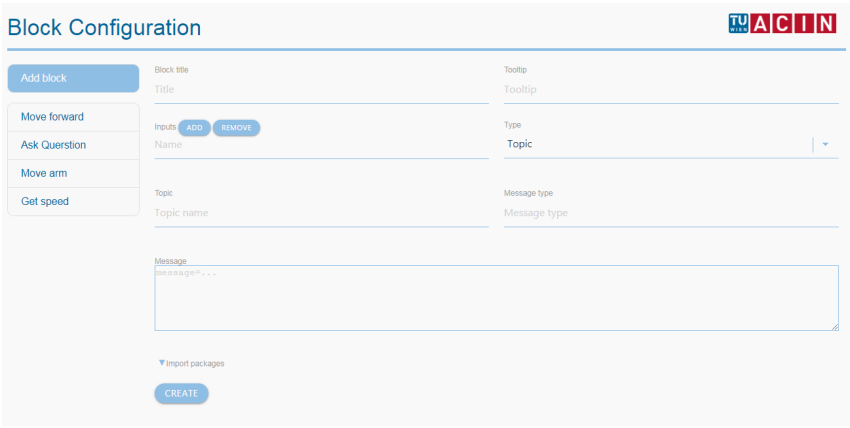


Figure 4.3: Design of the block configuration interface

The list of all already configured custom blocks is loaded via the GET request endpoint `/block/list` of the tool's internal RESTful API. The request delivers an object with the Blockly-conform block and code definitions, the unique ID and name of the respective block as well as the block's meta data. The latter is used to set the general and detailed forms in case the custom block is selected.

Identification which custom block is selected is handeld via the query string of the URL, which is set to the custom block's ID if it is selected. The ID of a block is an alphanumerical 12-character string, which is generated randomly.

The general information form is primarily used to set the visual design of the block. The user can configure the title and tooltip of the block as well as the number and names of the inputs, which then can be used in the detail section. The detail section varies depending on which type of the ROS communicating patterns is used. A topic must be specified by its name, the message type and the message itself. If the user wants to create a custom block for calling services, it is necessary to provide the name of the service, the message type and a list of all message type specific fields with their values. Furthermore, it is possible to choose whether the response of the service should be used as output - which will lead to an input block - or not - then an execution block is generated (Figure 4.2). The detail section for actions includes fields for setting the execution timeout (which is defined as the time to wait for the goal to complete), the server name, the message type and the goal. It is also possible to provide the following callback functions:

- done_cb: callback that gets called on transitions to *Done* state.
- active_cb: callback that gets called on transitions to *Active* state.
- feedback_cb: callback that gets called whenever feedback for the goal is received.

All detail sections also features an input field for importing all Python packages that are needed to execute the code correctly, e.g. messages types that are used to generate the message. Some step-by-step examples for configuring custom blocks are presented in Appendix B.

4.4 Code Generation

Demos are created via the user interface shown in Figure 4.4. It can be devided into three sections:

I. the **navigation header** holds elements to directly manage the current demo,

II. the **toolbox** contains code blocks organized in categories,

III. the **workspace** where the blocks can be dragged to from the toolbox and be connected with each other.

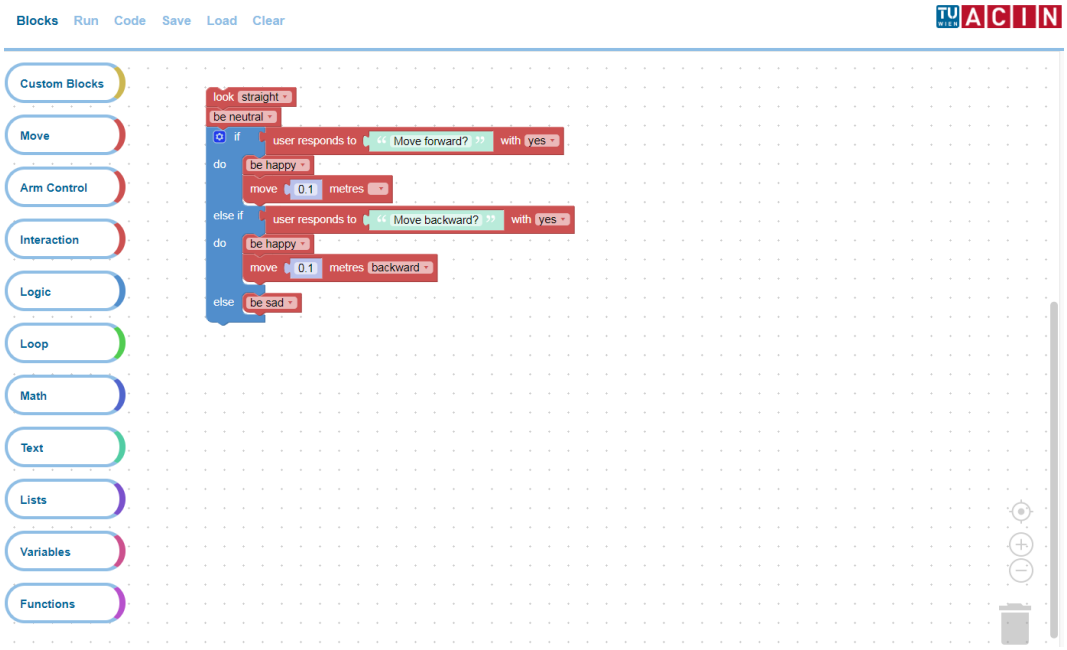


Figure 4.4: User interface for demo and code generation

Blocks which are dragged to and combined at the workspace are used to generate an executable code. This is done with the help of Blockly (see Section 3.2.3). Blockly came up with some predefined code blocks that allow some basic programming procedures. On top of them Rockly provides further blocks, which allows to connect to HOBBIT and perform several actions (Table 3.1). A list and description of these blocks can be found in Appendix C. All of them are using one of the mentioned ROS communicating pattern (topic, service, action) to call the interface of the robot and have a similar structure thanks to the design of a custom Python module (Section 4.6).

To get a clearer understanding of the general structure of these blocks and the Blockly custom block creation (Section 3.2.3) an explicit example is presented. The choosen example shows the block and code definition to create a block, which allows to move HOBBIT for a given distance into a given direction (Figure 4.5).

Figure 4.5: Example block to be created

```
Blockly.Blocks['hobbit_move'] = {
  init: function () {
    this.jsonInit({
      "type": "hobbit_move",
      "message0": "move %1 metres %2",
      "args0": [
        {
          "type": "input_value",
          "name": "distance",
          "check": "Number"
        },
        {
          "type": "field_dropdown",
          "name": "direction",
          "options": [
            [
              "forward",
              "+"
            ],
            [
              "backward",
              "-"
            ]
          ]
        }
      ],
      "previousStatement": null,
      "nextStatement": null,
      "colour": Blockly.Constants.hobbit.HUE,
      "tooltip": "Move HOBBIT",
      "helpUrl": ""
    });
  }
};
```

Listing 4.1: Full block initialization for moving HOBBIT forward and backward

The full block definition for the mentioned example is given in Listing 4.1. Lines 2 and 3 indicates, that the block is initialized using a JavaScript function (same as in Listing 3.3). In lines 1 and 4 the name and type of the block are set, which is important to get the corresponding code object later on. The `message0` key is used to set the message displayed on the block, whereas the placeholders (%1,%2) are replaced by the arguments given by the objects passed to the `args0` key. In the presented case the first argument is an input field and must be a number (lines 8,10) and the second one (lines 13 to 24) a dropdown field with options "forward" and "backward" displayed. In order to get the passed values for code generation a name for each paramter is set (lines 9,14). Lines 27 and 28 indicates that the block has connections on the top and bottom, but there are no constraints for them. The last three lines are just used to set the color, tooltip and an optional help URL.

```
1 Blockly.Python['hobbit_move'] = function(block) {
2   var value_distance = Blockly.Python.valueToCode(block
      , 'distance', Blockly.Python.ORDER_ATOMIC);
3   var dropdown_direction = block.getFieldValue('
      direction');
4   Blockly.Python.InitROS();
5
6   var code = Blockly.Python.NodeName+'.move('+
      dropdown_direction+value_distance+')\n';
7   return code;
8 };
```

Listing 4.2: Full code initialization for moving HOBBIT forward and backward

The corresponding code initialization is shown in Listing 4.2. Line 1 again shows the internal design of Blockly, which is based on assigning functions and objects to classes. Blockly supports code generation for several programming languages, which all are implemented in seperate classes. Since the presented tool should convert blocks into Python code, the Python class is used. Within the code initialization the input values of the block are read through the provided API first (line 2,3). Then some ROS specific initialization is done (line 4), which basically handles the import of the rospy package and the custom Python module as well as creating a ROS node. The name of the node is defined by the constant string `Blockly.Python.NodeName` and an instance of a certain class of the Python module. `Blockly.Python.InitROS()` is a custom command and must be included in the code initialization of each block. Finally, the code string is assembled by just calling the corresponding control function

of the ROS node instance with the input parameters (line 6) and then returned (line 7).

The code initialization of each created block follows the mentioned steps, which can be summarized as follows:

1. Getting the values of the inputs.
2. Initialization of the ROS interface
3. Assembly of the code string by simply calling the responding functions of the Python module

This generic design is another decrease of the conditions - in terms of JavaScript knowledge - for using the Blockly framework, because it outsources the main and most complex task of assembling the executing code to an interface more robot programmers are familiar with. Futhermore Google provides a visual interface - using the Blockly framework itself - to easily create the block configuration object.[1]

4.5 Code Editor

The generated code can be accessed by clicking on the *Code* tab on the user interface (Figure 4.4). It provides the opportunity to add further functionality to the code, which is not already covered by the tool, before executing the demo or saving it. This could be very basic modification, e.g. just adding comments to the code or inserting debugging messages, or more advanced ones, e.g. adding the functionality to subscribe to a topic.

This makes Rockly not only to be a stand-alone solution for basic use cases, but a supporting tool for more experienced users, who do not want to build their code from scratch.

The implementation of the provided editor basically involve just embedding Ace via its API (see Section 3.4.2). The basic embedding code is shown in Listing 4.3. It also shows how connected blocks on the workspace are translated into an executable Python code using the Blockly API (Line 2) and to display the generated code (Line 10). The variable *workspace* is an instance of the static class *Blockly.Workspace*[2].

[1] https://blockly-demo.appspot.com/static/demos/blockfactory/index.html
[2] https://developers.google.com/blockly/reference/js/Blockly

```
1  // Generate code from workspace
2  var code = Blockly.Python.workspaceToCode(workspace);
3  // Create Ace instance and set preferences
4  var editor = ace.edit("editor");
5  editor.setTheme("ace/theme/chrome");
6  editor.getSession().setMode("ace/mode/python");
7  editor.getSession().setUseWrapMode(true);
8  editor.setShowPrintMargin(false);
9  // Display code
10 editor.setValue(code);
```

Listing 4.3: Embedding Ace, setting preferences and displaying generated code

4.6 Python Module

As described above each block of the HOBBIT block set calls a corresponding method of the ROS node class inside the custom Python module, which then calls generic communication methods. This section describes how the module is set up and the generic methods to initiate the ROS communication for each communication pattern are implemented. It is desigend as shown in Figure 3.2 with a class containing the necessary properties and methods. For all listings debugging messages are excluded.

Initialization

For any form of communication between the nodes, they have to register to the so called ROS Master - the master node, which provides naming and registration services to the rest of the nodes in the ROS system. It has to be started as the first process, which in the case of HOBBIT is done during the booting process. Therefore, the initialization process of the custom Python module only needs to register a new client node. This is done by simply calling the corresponding `init_node` method[3] of the rospy package, which takes the node's name as parameter. Duplicate calls to `init_node` are forbidden, for which reason the `Blockly.Python.InitROS()` method inside every block was introduced as mentioned in Section 4.4. It ensures that `init_node` is called from the main Python thread.

[3] http://docs.ros.org/jade/api/rospy/html/rospy-module.html#init_node

Publishing to a topic

For publishing to a topic the `rospy.Publisher` class[4] of the rospy package is used. It takes two mandatory initialization paramters: the resource name of topic as a string and the message class. The publishing itself is executed by calling the `publish` method of the class. It can either be called with the message instance to publish or with the constructor arguments for a new message instance. The full implementation of the generic publishing method is shown in Listing 4.4. There are a few important things to be considered. First, an instance of the `rospy.Rate` class[5] is created to ensure the publisher is instanced and the message is published. Second, the `exec` Python built-in function is used, so that any manipulation by the user should be prevented. This is ensured by encapsulating the generic function as mentioned in the beginning of this section. Last, all message classes for the implemented commands (Table 3.1) are imported at the beginning in order to successfully execute the `exec` statement.

```
1 def publishTopic(self, topic, message_type, message):
2     rate = rospy.Rate(1)
3     exec('pub = rospy.Publisher(\''+topic+'\', '+
          message_type+', queue_size=10)')
4     rate.sleep()
5     pub.publish(message)
6     rate.sleep()
```

Listing 4.4: Implementation of a generic method to publish to a ROS topic

Calling a service

To call ROS services it is first necessary to create an instance of the `rospy.ServiceProxy` class[6] with the name and class of the desired service. Then it is recommended to wait until the service is available - which is done by calling the `rospy.wait_for_service` method - before finally calling the instance. This basic steps are included in the generic service call method of the custom Python module (Listing 4.5). It can be structured into three parts: the two just mentioned - creating (lines 9 to 14) and calling the instance (lines 16 to 22) - and a parameter preparation part (lines 2 to 7).

The latter is introduced to create a simple and understandable execution statement when calling the service. Service parameters, which are passed as

[4] http://docs.ros.org/melodic/api/rospy/html/rospy.topics.Publisher-class.html
[5] http://docs.ros.org/jade/api/rospy/html/rospy.timer.Rate-class.html
[6] http://docs.ros.org/api/rospy/html/rospy.impl.tcpros_service.ServiceProxy-class.html

list to `callService` method, are splitted and assigned to temporary variables `par0,par1,...,parN`, where $N = k - 1$ and k being the number of service parameters. These temporary variables are then combined to a string, which seperates the parameters with a comma. This string then is passed to the execution statement. Additionally the basic error handling is outlined by excepting typical ROS provided exceptions.

```
1  def callService(self,ServiceName,ServiceType,args):
2      ParameterList = []
3      if args:
4          for i,arg in enumerate(args):
5              exec('par'+str(i)+'=arg')
6              ParameterList.append('par'+str(i))
7      parameters = ','.join(ParameterList)
8
9      try:
10         rospy.wait_for_service(ServiceName)
11         exec('servicecall = rospy.ServiceProxy(\''+
               ServiceName+'\',' +ServiceType+')')
12
13     except rospy.ROSException:
14         return None
15
16     try:
17         exec('req = '+ServiceType+'Request('+parameters
               +')')
18         resp = servicecall(req)
19         return resp
20
21     except rospy.ServiceException:
22         return None
```

Listing 4.5: Implementation of a generic method to call a ROS service

Sending a goal to an action server

Although the ROS actionlib is a very powerful component, its usage is very simple, as can be seen in Listing 4.6. The action client and server communicate over a set of topics. The action name describes the namespace containing these topics, and the action specification message describes what messages should be passed along these topics. This infos are necessary to construct a

`SimpleActionClient` and open connections to an `ActionServer`[7] (line 2). Before sending the goal to the server it is requiered to wait until the connection to the server is established. Afterwards an optional argument (`timeout`) decides how long the client should wait for the result before continuing its code execution and returning the result.

```
1 def sendActionGoal(self, namespace, action_type, goal,
     timeout = rospy.Duration()):
2     exec('client = actionlib.SimpleActionClient(\''+
         namespace+'\', '+action_type+')')
3     client.wait_for_server()
4     client.send_goal(goal)
5     client.wait_for_result(timeout)
6     return client.get_result()
```

Listing 4.6: Implementation of a generic method to use the actionlib

4.7 Storage Management

For reasons of simplicity all necessary data - such as demos, executable codes or custom blocks - are stored in raw files on the robots. They are managed by a own service within the backend. It uses the file system module (*fs*)[8] of Node.js. All of its file system operations have synchronous and asynchronous forms. Both are used in the implementation. The following functionalites are implemented using the storage management service:

- Listing all demos
- Saving, deleting, showing and running a specific demo
- Listing all custom blocks
- Creating, editing and deleting a custom block
- Providing the toolbox of Blockly's workspace

Listing resources - i.e. demos and blocks - following a simple read-and-send algorithm. The management of demos and blocks are slightly different, because informations of blocks are stored in a single file, while informations of demos

[7] http://docs.ros.org/jade/api/actionlib/html/classactionlib_1_1ActionServer.html
[8] https://nodejs.org/api/fs.html

are spread to multiple files and directories. A more detailed explanation of the latter is given in Section 4.8. The toolbox is assembled in two steps. The structure of the basic toolbox - including the HOBBIT block set and the predefined code blocks of Blockly - is stored in an `.xml` file. This allows the user to reorganize the toolbox to his preferences just following the description mentioned in Section 3.2.3 and without any necessity to touch the code. After reading the basic toolbox information, the storage management services checks whether there are any custom blocks created already, and, if so, appends them to the toolbox.

4.8 Code Execution

The code generated through the blockly framework (Section 4.4) and optionally edited by the user (Section 4.5) is saved in a `.py` file seperatley from the demo `.xml` file. Although this leads to slightly more effort in terms of maintaining the tool, it also has an important advantage: it provides the ability to reuse the code indepently from the raw block data and the tool itself, e.g. for building more complex demos and ROS nodes, running it from the command line or simply sharing it. In other words, it is not even necessary to run the tool on the robot itself. Of course, there is also the option to run the code directly from Rockly via the integrated *Run* button of the user interface (Figure 4.4). In this case the corresponding request to the backend (`/demo/run/`, see Table 4.1) is send, including the code inside the request body. The backend then executes the code using the *child_process* module[9] of Node.js.

[9] https://nodejs.org/api/child_process.html

5 Evaluation

The following chapter describes how the implemented tool was evaluated. An experiment was used for that purpose which will be described in the following sections. Furthermore, the data acquisition is presented as well as how this data was analysed.

5.1 Experiment Setup

The implemented tool was evaluated with X professional robotics software developers from the V4R group of the automation and control insitute at the TU Wien. This section describes the goals and design of the experiment as well as the questions the participants were asked.

5.1.1 Goals of the Experiment

The following goal questions (GQ) should be answerd by the experiment:

- *GQ1*: Is the tool seen as an improvement compared to the traditional coding approach?
- *GQ2*: Do participants make less pauses when they use the tool compared to coding?
- *GQ3*: Does it take less time to find solutions when using the tool?
- *GQ4*: Is the usage of the tool is intuitive?

All of the presented goal have in common that they can be answered positively, negatively and none of both. The third option means that furher research must be done, e.g. conducting further experiments to get an answer for this question.

The primary goal of this evaluation is to find out if the developed tool is seen as an improvement compared to the traditional coding approach. This question is described by *GQ1* and should be answerd by analysing the feedback of participants, who have experience in programming robotics - especially using ROS.

Also, the answers to workload questions can be taken in account. (Section 5.1.3)

GQ2 should give an answer to the question whether using the tool affects the workflow of the participants. Do they make less pauses when using the tool? Do they change the code more often when using the traditional approach? When do they struggle? To quantify this the measurements presented above are analysed as well as the answers to questions regarding the workload.

GQ3 simply should examine if using the tool saves time compared to the coding approach. Saving time when creating programms means more time for other work, which especially for users of the primary target group (see Section 3.1.2) is important, because it may not is the major content of their work or research.

Finally, *GQ4* should ...

5.1.2 Design

A cross over design was used for the experiment splitting the the participants into two groups. Therefore, two different use cases were designed, which are described in Section 5.1.4. For the first use case on group worked with the tool and the other group was asked to implement a code for the same use case. For the second use case roles where switched and participants which was working with the tool had to write a code and vice versa.

When working on the code the group was supported by material covering explanation of the necessary ROS concepts including examples. Furthermore a list of the necessary ROS specifications (topics, services, actions, messages etc.) were provided. The participants were asked to use a customized code editor, which were able to perform basic measurements. They were free to choose whether implementing in Python or C++. This instrumentation ensures that the results and measurements of both tasks are compareable in terms of exploring the impact of programming knowledge.

All materials, also including the task description of the use cases, were reviewed by a colleague not participating in the experiment in advance to guarantee its understandability and soundness. At the beginning of the experiment the tool was introduced using a short live demo showing all concepts and how it should be worked with the tool and the code editor, respectivley. The participants worked on each task for a total of XX minutes.

While working on the use cases two measurements are performed for each participant: total time (the time to accomplish tasks) and pauses (number of

occurrences, where the programm has not changed within XX seconds during development). The measurements are done for both task, working with Rockly and coding. For this purpose a routine using the Blockly API was implemented, which listens to changes in the tool's workspace - i.e. creating, updating or deleting blocks. The provided editor was also customized with a feature, which recorded the timestamps of changes. At the start of each task the participants had to click on a *Start* button, which started the timer. It was stopped, when the participant clicked the *Stop* button. The implemented function then submitted the following information:

- User ID: a randomly generated alphanumeric ID to assign submissions
- Total time taken to accomplish task
- Timestamps of pauses
- Type of submission (tool or code)
- Content of submission (e.g. full code)

5.1.3 Questionnaire

Additionally to the mentioned time based measurements a questionnaire was also included into the evaluation process. The participants were asked to answer them after they completed both tasks. The questions can be classified into four categories: demographic factors (DF), experience questions (EQ), feedback questions (FQ) and workload questions (WQ). Each of them are discussed in the following.

Demographic Factors

Demographic questions are designed to help survey researchers determine what factors may influence a respondent's answers, interests, and opinions. Participants of this experiment were asked the following questions:

- *DF1*: What is your age?
- *DF2*: What is your highest qualification?
- *DF3*: What is your current employment status?
- *DF4*: What is your current field of work/study?

DF1 was asked to roughly determine the participant's knowledge and experience. The possible answers ranged from *under 18* to *above 44*. A more detailed information regarding the general knowledge of the participant is delivered by question *DF2*. The possible answers were: less than high school, high school diploma or equivalent degree, bachelor's degree, master's degree, higher than master's degree, no degree. Questions *DF3* and *DF4* were asked to determine whether a participant has experience in any related field and, if so, how much.

Experience Questions

The main motivation for having experience questions is that they enable the correlation between results of the experiment and the experience for each participant. The following questions were asked to collect this information:

- *EQ1*: How much experience do you have with ROS?
- *EQ2*: How much experience do you have with programming in C++/Python?
- *EQ3*: How much experience do you have with programming in general?
- *EQ4*: How much experience do you have with block-based VPLs (e.g. Blockly)?

A scale including the answers *none*, *moderate* and *expert* was used. The answers can easily be mapped onto a numeric scale. The set of answers was also chosen to be that limited to minimize the variability of the answers. The questions are structured according to the level of abstraction. In particular *EQ1* was chosen since the implemented tool provides an environment which should support people without detailed knowledge of ROS. Experience with ROS therefore could influence the outcome of the experiment. Another influence could be the programming experience in C++ and Python, which are the main languages for programming ROS nodes (see *EQ2*). Especially when comparing the results of the coding task, this could explain differences. General programming experience may not influence the coding task, but could decrease the effort when working with the tool - e.g. when looking at the participants' pauses (see *EQ3*). Participants with experience in block-based languages are expected to find their way through the Rockly workspace more easily than novices (see *EQ4*).

Feedback Questions

The motivation for the asking feedback questions is to get subjective feedback from each participant which should help, together with the analysis of the

other mentioned measurements, to answer all the goal questions presented in Section 5.1.1. The following feedback questions were asked:

- *FQ1*: Do you think such a tool saves time compared to your current approach?
- *FQ2*: Do you think such a tool allows more flexibility compared to your current approach?
- *FQ3*: Do you think such a tool provides scalable solutions for tasks you are facing in your work?
- *FQ4*: Do you think the usage of the tool is intuitive?

The scale used for the questions included the following possbile answers: *Strongly disagree*, *Disagree*, *Neutral*, *Agree*, *Strongly agree*. Again, the motivation for choosing this set of answers was to minimize the variability of answers. Especially when looking on *GQ1*, the feedback questions play a crucial part in this experiment.

FQ1 should find out if such a tool is seen as assistance for topics the participants are facing during their work. As mentioned, programming a robot is not necessarily the main topic in research projects. Having a tool, which speeds up subtasks, allows to spend more time on more crucial tasks. The subjective answers to this question can also be compared to the result of the measurements.

FQ2 targets the flexibility of the tool, e.g. when thinking of creating different demos. It basically gives insights on how much complexitivity can be put into demos when implementing them with the tool.

Similar to that question, *FQ3* would also affect the judgement if the tool is seen as an improvement or not. If solutions can not be implemented flexible and scalable enough, more research is required to further improve the presented tool.

Finally, *FQ4* should find out how intuitive the usage of the tool is regarding a participant's subjective feeling. Having an intuitive tool and workflow helps a visual programming tool to be accepted by potential users. Experienced users probably would tend to use it over self-implemented code because it saves time and unexperienced users may faster understand programming concepts.

Workload Questions

Besides getting direct feedback from participants another approach, judging how useful and intuitive a tool is, can be measuring the workload a participant felt during working with it. Because of that, another set of questions was included in the evaluation process. It is based on the NASA Task Load Index (NASA-TLX)[28], which consists of six subscales that represent somewhat independent clusters of variables: mental demand, physical demand, temporal demand, frustration, effort and performance. The assumption is that some combination of these dimensions are likely to represent the workload experienced by most people performing most tasks. The following four workload questions were asked for both tasks, working with the tool and writing a code:

- *WQ1*: How mentally demanding was the task?
- *WQ2*: How much time pressure did you feel during the task?
- *WQ3*: How hard did you have to work to accomplish your level of performance?
- *WQ4*: How insecure, discouraged, irritated, stressed and annoyed were you?

The number of questions was limited to four, because two clusterd variables are not seen to be required in the scope of the chosen experiment setup. First, it can be expected that working with a software tool is not considered to be physical demanding. Second, the participants may cannot rate their performance properly because debugging and testing is not supported by the experiment setup. Further adaption was done in respect of the number of possible answers. In the official NASA-TLX paper and pencil version[1] increments of high, medium and low estimates for each point result in 21 gradations on the scales. To minimize the variability of answers only a scale with five gradations (*Very low*, *Low*, *Medium*, *High*, *Very high*) was used.

5.1.4 Use Cases

This section presents the use cases the participants were asked to work on. It starts with the description of each use case, then the required ROS specifications are explained and finally flowcharts for better understanding are presented. The use cases were designed to be compareable in terms of complexitivity, which in this context is quantifed by the amount, type and distribution of different ROS communication patterns as well as the total amount of ROS message calls.

[1] https://humansystems.arc.nasa.gov/groups/TLX/downloads/TLXScale.pdf

Action	Type	Specification	Calls
Move head	Topic	/head/move	2
Show emotion	Topic	/head/emo	1
Move arm	Action	hobbit_arm	4
User interaction	Service	/MMUI	7

Table 5.1: ROS patterns used for implementing first use case

Learning a new object

The first task the participants were asked to work on was a behaviour, which is already implemented on HOBBIT: learning a new object. The participants should find a solution with the traditional way, meaning writing the full code by themselves. They were provided with a additional materials, which should give them support to start not purely from the scratch.

The use case can be described as follows: First HOBBIT should grab the turntable from its storing position. Then a message on its tablet should be shown to ask the user to put an object on the table. After the user confirmed the placement, HOBBIT should look at the object on the turntable and tell the user "I'm learning a new object" via its tablet interface. The table should turn clockwise first, before the user should be asked to place the the object upside down on the table. Again, the robot should wait for confirmation, then telling "I'm learning a new object" wihle rotating the table counterclockwise. After that, the user should be asked to remove the object and confirm this. Then HOBBIT should look straight, store the table and ask for the name of the object. Finally HOBBIT should show a happy emotion and tell "Thank you, now I know what X is", where X is the name of the object. The whole desired workflow is visualed in Figure 5.1. Furhter, Table 5.1 breaks down the complexitivity of the first use case. It is necessary to publish to two different topics, implementing one action client and calling one service.

Bringing objects from another person

The second use case was perform by using the Rockly environment. There were no additional supporting materials. Instead a short introduction on how to use the tool was given. The time cap was the same as in the first use case.

The task was to implement a programm to ask the user repetitively if HOBBIT should bring an object from another person, which is located at another

Figure 5.1: Flowchart of first use case

Action	Type	Specification	Calls
Show emotion	Topic	/head/emo	1
Move arm	Action	hobbit_arm	4
Navigation	Action	move_base_simple	2
User interaction	Service	/MMUI	6

Table 5.2: ROS patterns used for implementing first second case

place. First the user should be asked which objects should be picked up (e.g. "Which object do you want?"). The user then should use the robot's tablet to enter the name of the requested object. After that, HOBBIT should navigate to the second person. The exact location, specified by the coordinates and pose, was provided in advance to the participants. The second user then should be asked to handover the desired object. If it is answerd positively, the object should be placed on HOBBIT tray and the robot navigates back to its previous location telling the user "Here you are" and placing the object on the table. If the object has not been handed over, an appropriate message should be displayed on the tablet (e.g. "I'm sorry, your partner couldn't handover the object") after navigating back. Afterwards the user should be asked, if HOBBIT should bring another item. The whole procedure should be performed as long as the user does not request another object. After the final decline HOBBIT should show a happy emotion again. For a better understanding Figure 5.2 provides the flowchart of this use case.

Table 5.2 breaks down the complexitivity of this use case. It is necessary to publish to one topic, make calls from two different action clients and use one service. So the number of different ROS communication types is equal to the first use case. The total number of necessary calls differ slightly (14 in the first use case, 13 in the second). This should be compensated by asking for implementing just one action server for the first use case and publishing to two topics (compared to two actions and one topic for the second use case), since this actions are seen as the most difficult ROS pattern and topics the most simple ones.

5.2 Results

5.3 Discussion

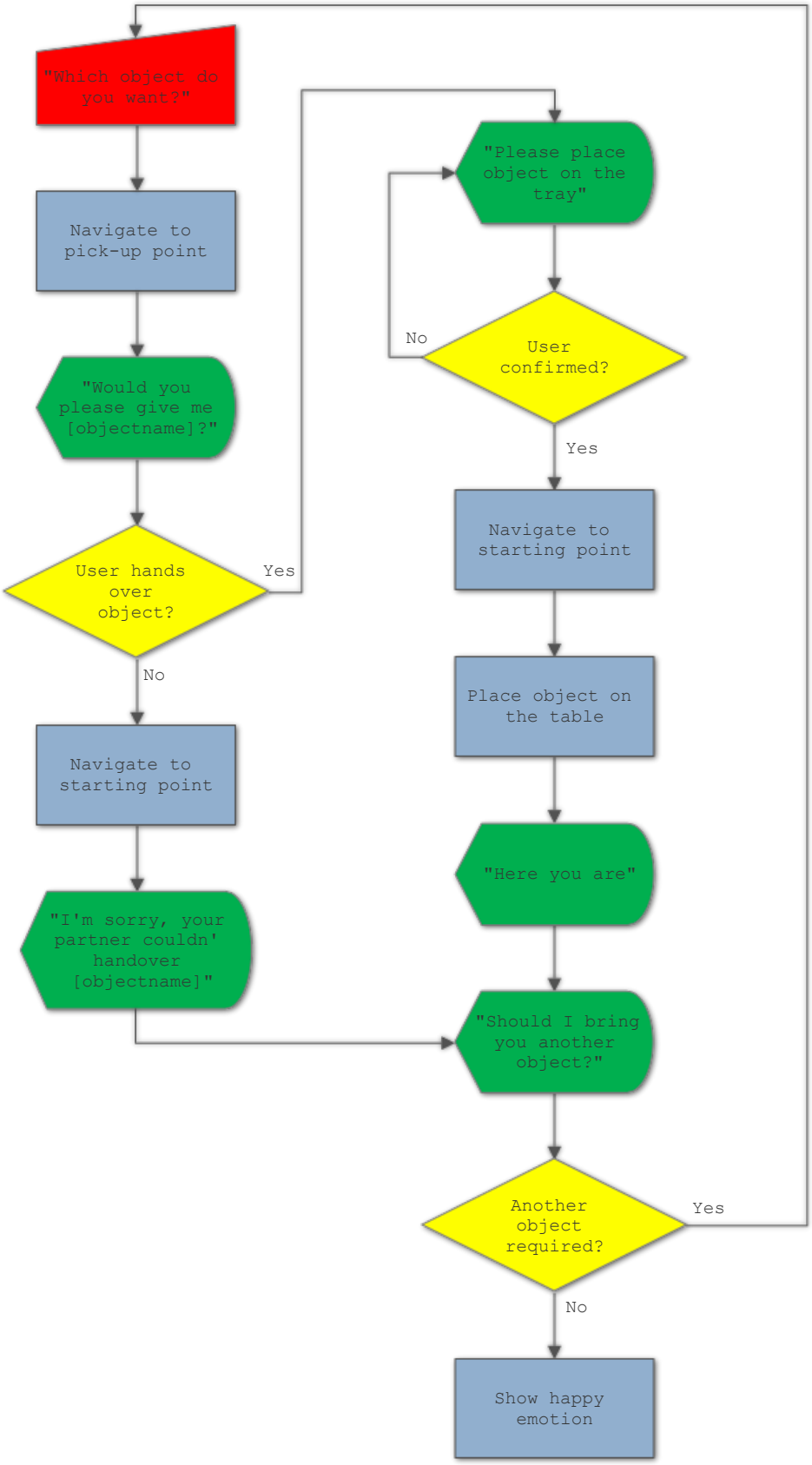


Figure 5.2: Flowchart of second use case

6 Conclusion

Appendices

A List of Abbreviations

API Application Programming Interface

IDE Integrated Development Environment

NASA-TLX NASA Task Load Index

PLC Programmable Logic Controller

ROS Robot Operating System

SDK Software Development Kit

SFC Sequential Function Chart

UI User Interface

VPL Visual Programming Language

XML Extensible Markup Language

B Block configuration manual

This appendix shows step-by-step examples for configuring custom blocks using Rockly's block configurator for each of the following ROS communication patterns:

- Topic
- Service
- Action

Custom block publishing to a topic

This example creates a custom block, which sending a message to a ROS based robot. The filled form is shown in Figure B.1, the final design is shown in Figure B.2.

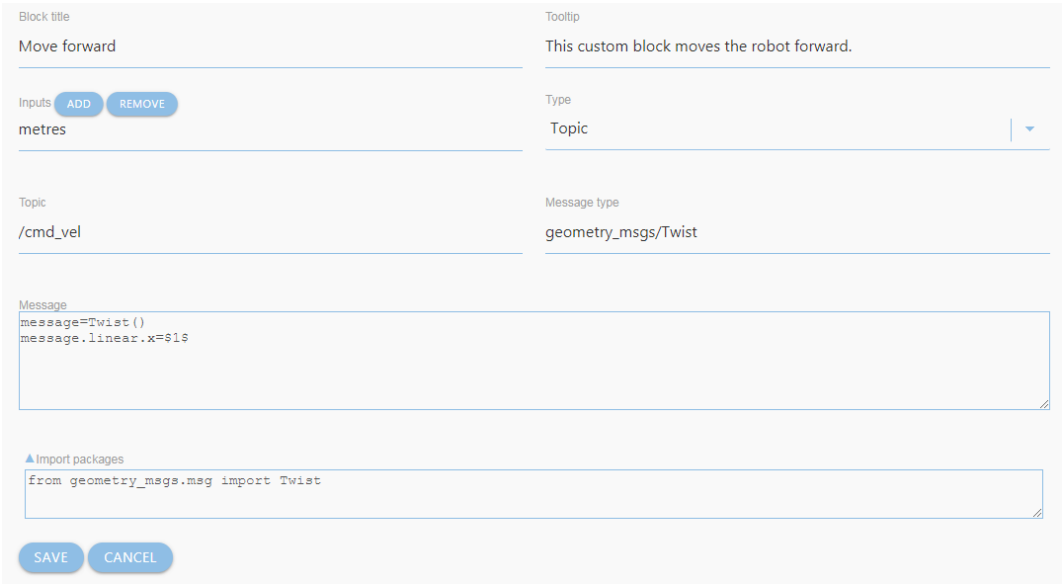


Figure B.1: Filled form to create a custom block publishing to a topic

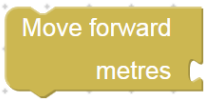


Figure B.2: Resulting custom block using the block configuration shown in Figure B.1

```
#!/usr/bin/env python
import HobbitLib
import rospy
from geometry_msgs.msg import Twist


if __name__ == '__main__':
  try:
    DemoNode = HobbitLib.node('DemoNode')

    message=Twist()
    message.linear.x=1
    HobbitLib.importMsg('geometry_msgs.msg','Twist')
    DemoNode.publishTopic('/cmd_vel', 'Twist', message)

  except rospy.ROSInterruptException:
    pass
```

Listing B.1: Examplary generated code using the block shown in Figure B.2

The given title and inputs of the block are can be observed, when looking at the block. The tooltip only appears on mouseover events. All other information is used to generate the code. The value of an input - which is passed by connecting the corresponding input - can be used for the message creation by putting a placeholder `$n$` (with n being the n-th input in the list - counting top down) to it. It is possible to put any code to the *message* field, but it is necessary that it includes an assignment of the `message` value. Assuming the value *1* is passed to the input, the code shown in Listing B.1 will be generated.

Custom block calling a service

Within this section the creation of an example block, which calls a service, is shown. The block can be used to ask a question to the the user and use the response as output, so that the block can be connected as input to another block. The configuration form for this block is shown in Figure B.3.

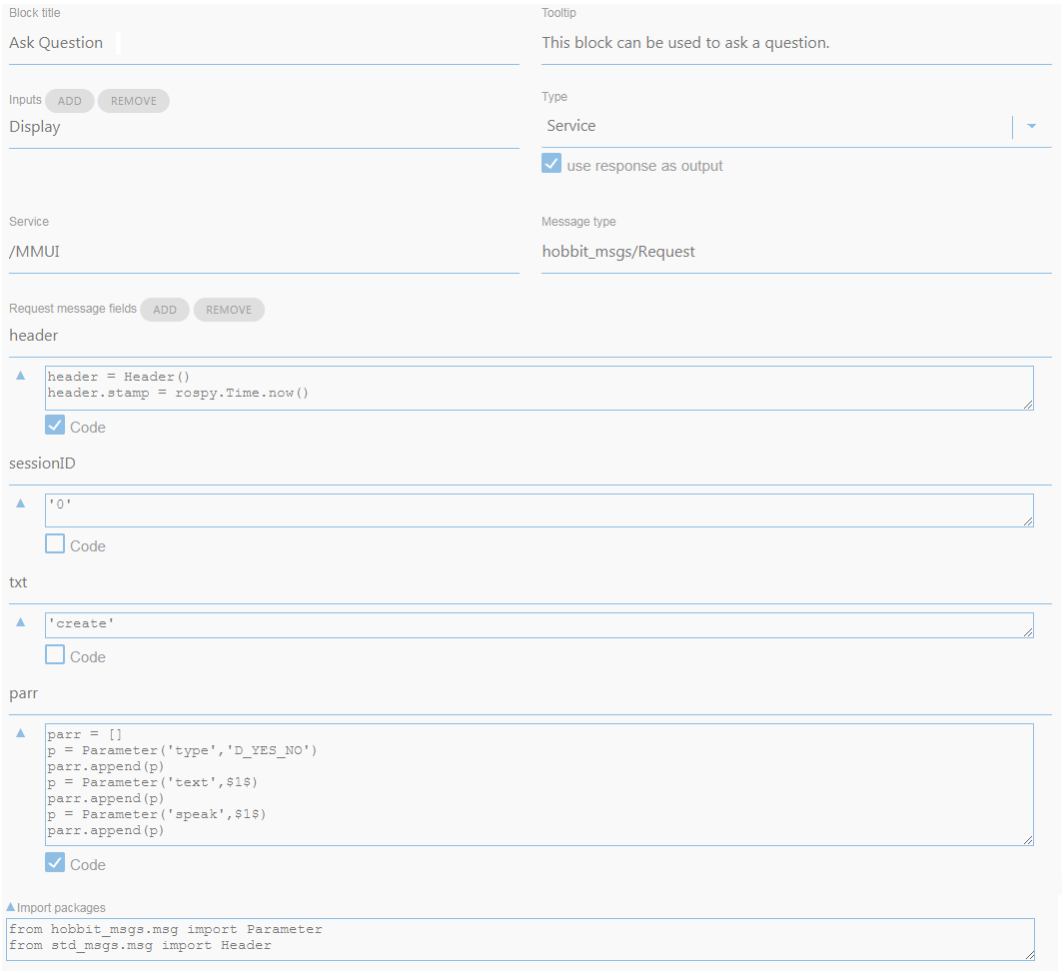


Figure B.3: Filled form to create a custom block calling a service

Besides the choice to use *Service* as communication pattern and pass the service's response, there's no noteworthy difference compared to Section B. In the service-specific section first the service's name (*/MMUI*) and message type (*hobbit_msgs/Request*) are set, then the request message fields are configured. There are two different ways of doing that:

- providing a key-value pair, or
- using a code block.

In the first case the key-value pair is just translated into a String containing the given info. If the latter one is used, it is necessary that the code includes a explicit assignment of the corresponding request message field. In the given

example `parr` is set via a code block. Note that the name of the field is identically the same as the variable's name. By the way, the same effect could be achieved using a key-value pair with the following value:

`[Parameter('type','D_YES_NO'),Parameter('text',$1$),Parameter('speak',$1$)]`.

Again, using the values of the blocks connected to the inputs can be included by putting the placeholder to the corresponding field, as explained in Section B. A exemplary use of the just created custom block is presented in Figure B.4 with Listing B.2 showing the generated code.

Custom block using actionlib

Figure B.5 shows how a custom block can be defined, if it is desired that the block should send a goal to an action server.

```
#!/usr/bin/env python
import HobbitLib
import rospy
from hobbit_msgs.srv import Request
from hobbit_msgs.srv import RequestRequest
from hobbit_msgs.msg import Parameter
from std_msgs.msg import Header

def srv21zxtebqdd3i():
  header = Header()
  header.stamp = rospy.Time.now()
  sessionID='0'
  txt='create'
  parr = []
  p = Parameter('type','D_YES_NO')
  parr.append(p)
  p = Parameter('text','Are you happy?')
  parr.append(p)
  p = Parameter('speak','Are you happy?')
  parr.append(p)
  reqparams=(header,sessionID,txt,parr)
  return DemoNode.callService('/MMUI', 'Request',
     reqparams)

if __name__ == '__main__':
  try:
    DemoNode = HobbitLib.node('DemoNode')
    HobbitLib.importMsg('hobbit_msgs.srv','Request')

    print(srv21zxtebqdd3i())

  except rospy.ROSInterruptException:
    pass
```

Listing B.2: Generated code of the block connections shown in Figure B.4

Figure B.4: Exemplary us of the custom block created using the block configuration shown in Figure B.3

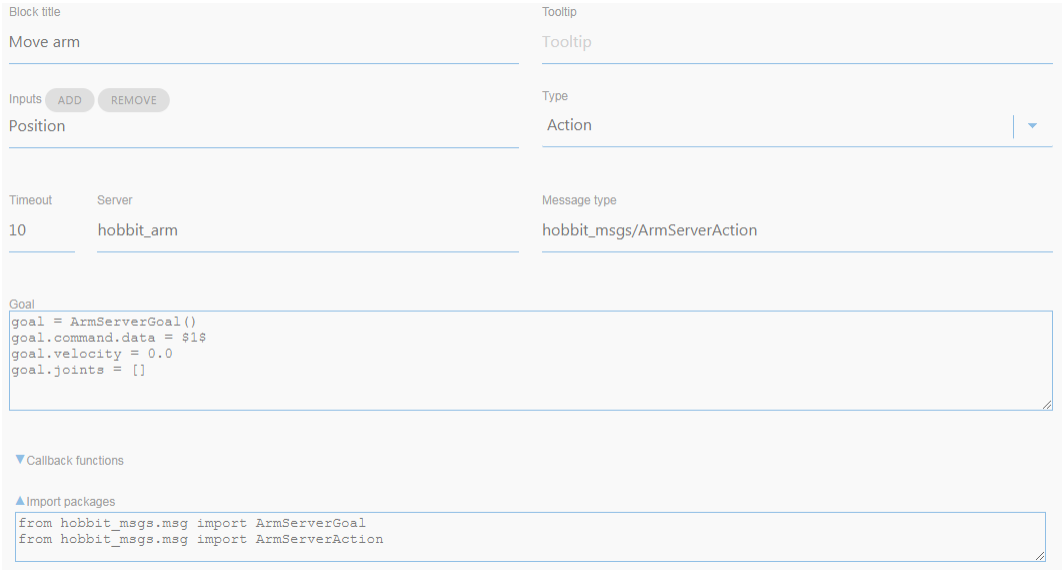


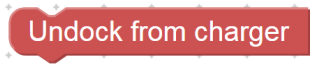
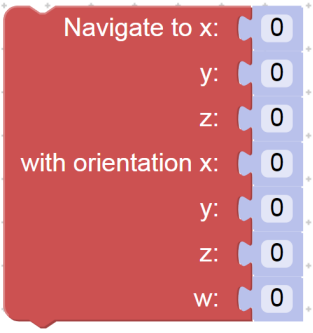
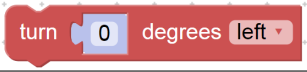
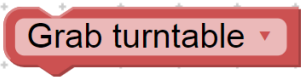
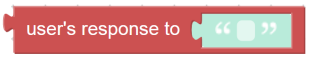
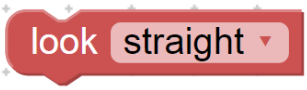
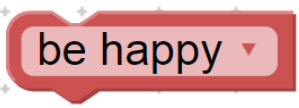
Figure B.5: Filled form to create a custom block using actionlib

C HOBBIT block set overview

The blocks of Rockly' toolbox are divided in the following categories:

- Custom Blocks: all blocks which are created with the block configuraton interface (Section 4.3)
- Move: blocks to move HOBBIT
- Arm Control: blocks, which allows to move HOBBIT's arm
- Interaction: any form of blocks, which allows HOBBIT to communicate with the user
- Logic: collection of Blockly's predefined logic blocks
- Loop: collection of Blockly's predefined looping blocks
- Math: collection of Blockly's predefined math blocks
- Text: collection of Blockly's predefined text blocks
- Lists: collection of Blockly's predefined list blocks
- Variables: a category to create and use variables
- Functions: a category to create and use functions

This section contains an overview of all blocks created for HOBBIT's interface, a description of Blockly's predefined blocks can be found in [29].

Block	Description
	Undock HOBBIT from charger
	Move HOBBIT in the given direction
	Navigate to given pose
	Rotate HOBBIT in the given direction
	Move HOBBIT's arm to the given position
	Perform the given action with the turntable
	Open or close the gripper
	Show an info on HOBBIT's tablet
	Show an info on HOBBIT's tablet and wait for confirmation
	Get user's answer to a yesâ€“no question
	Display the given question on HOBBIT's tablet and get user's answ
	Move HOBBIT's head to the given position
	Set HOBBIT's eyes according to the given emotion

D ROS reference for HOBBIT

Message	Description
'center_center'	look straight
'center_right'	look to the right
'center_left'	look to the left
'up_center'	look up
'up_right'	look to the upper right corner
'up_left'	look to the left left corner
'down_center'	look down
'down_right'	look to the lower right corner
'down_left'	look to the lower left corner
'littledown_center'	look little down
'to_grasp'	look to grasp position
'to_turntable'	look to turntable

Table D.1: Possible messages for topic */head/move*

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