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Department of Technology & Life Sciences

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Software report

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Mobile Robotics (MECH-M-2-ROB)

about

TurtlesimAutomata - a first dip into ROS2

from

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Contents

Chapter 1

Introduction

The turtlesimAutomata package is a ROS2 (Robot Operating System) [1] package that uses a finite state machine-like structure to control a turtle in the turtlesim [2] environment. It's purpose is to provide an entry-level example of a ROS2 package to acquaint the user with the basic concepts of ROS2. The turtlesimAutomata package is closely intertwined with the turtlesim package, which is a simple simulator for a mobile robot in the shape of a turtle.

1.1 Assignement

The assignement stated the following requirements for the turtlesimAutomata package:

- The turtlesimAutomata package should work closely together with the turtlesim package.
- The turtle shall start off in a random direction
- The turtle shall move in a straight line until it reaches the edge of the turtlesim window, at which point it shall make a 90 degree turn in clockwise direction and continue moving in the new direction.

Chapter 2

Package overview

The turtlesimAutomata package consists of the following nodes:

- /start_turtle listens to the */rosout* topic for a message containing "Spawning turtle" which indicates that the turtlesim_node node has started successfully. It will then send a randomly computed angle to the /turn_turtle node via the */turn_angle* topic and shut itself down afterwards.
- /drive_turtle_continuously continuously sends a message to the */turtle1/cmd_vel* topic to drive the turtle in a straight line. The sending of said message may be toggled via the */drive_turtle* topic.
- /turn_turtle listens to the */turn_angle* topic for a message containing the angle by which the turtle shall turn. The node includes a client for the */turtle1/teleport_relative* service (not visible in Figure 2.1), which is hosted by the /turtlesim_node and is being used to request a turn of the turtle by the received angle. The node functions mostly as a relay station.
- /edge listens to the */rosout* topic for a message containing "Oh no! I hit the wall!" which is published by the turtlesim_node node when the turtle reaches the edge of the window. It will then tell the /drive_turtle_continuously node to stop driving the turtle forwards, send a message via the */turn_angle* topic to request a 90 degree clockwise turn by the /turn_turtle node and afterwards tells the /drive_turtle_continuously node to continue driving the turtle forwards.

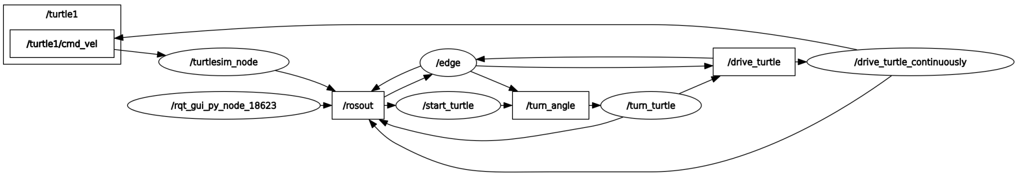
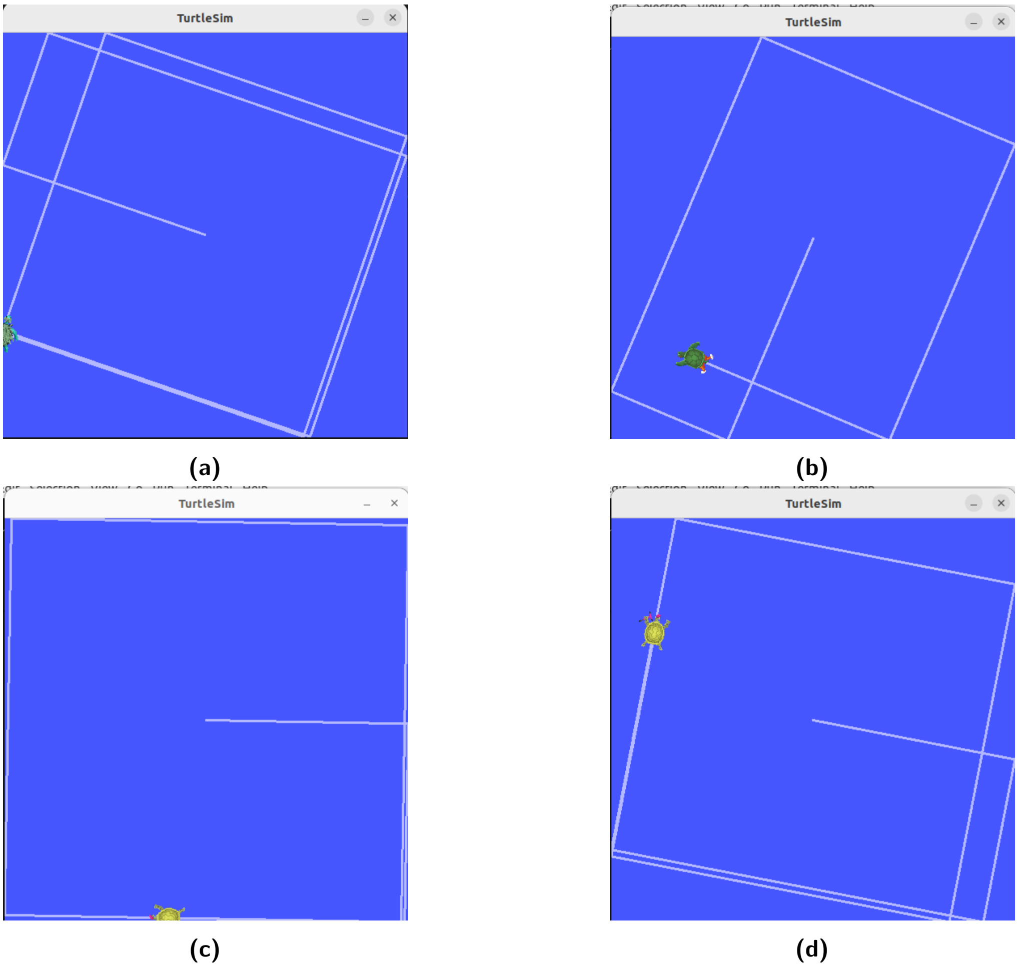


Figure 2.1. Nodes and topics of the turtlesimAutomata package shown in rqt_graph

Chapter 3

Behaviour of the turtle

The following Figure 3.1 shows examples of the turtle's behaviour, showcasing that the `turtlesimAutomata` package is working as intended.



(a)

(b)

(c)

(d)

Figure 3.1. Examples of the turtle's behaviour

Chapter 4

Additional functionalities

The `turtlesimAutomata` package can be used in combination with the `turtlesim_teleop` package, which allows the user to manually control the turtle in the turtlesim environment, whilst still maintaining the automatic behaviour provided by the `turtlesimAutomata` package. This may result in interesting behaviour, as shown in Figure 4.1.

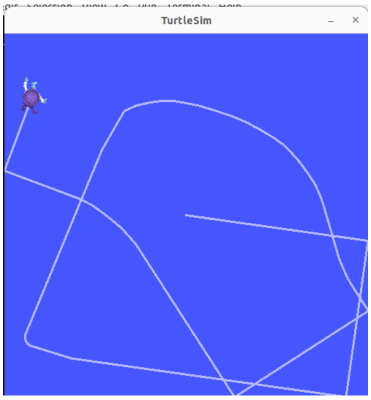


Figure 4.1. `turtlesimAutomata` and `turtlesim_teleop` working together

Figure 4.2 shows the `rqt_graph` of the `turtlesimAutomata` and `turtlesim_teleop` packages working together.

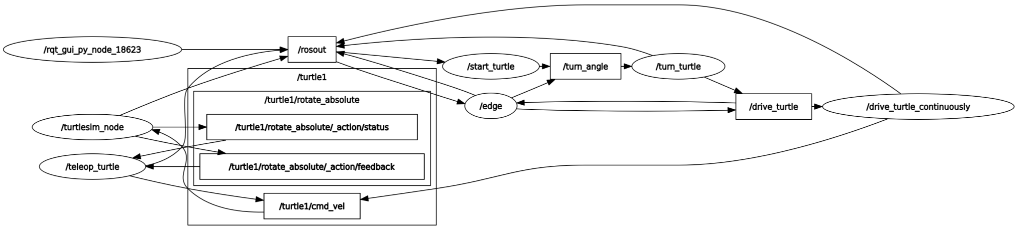


Figure 4.2. turtlesimAutomata and `turtlesim_teleop` working together shown in `rqt_graph`

Chapter 5

Possible improvements

The `turtlesimAutomata` package does a good job of fullfilling the given requirements. However, there are some possible improvements that could be made to the package.

For example, under certain conditions, the turtle may leave the window without the `turtlesim_node` noticing, which sometimes results in the turtle going off into the void. This could be fixed by either polling the turtle's current pose (and making sure it is still in the window coordinates) or by making use of the message sent by the `turtlesim_node` when the turtle unexpectedly left the window.

Currently the `turtlesimAutomata` package uses the */teleport_relative* service to turn the turtle. This may also be done via the */rotate_absolute* action, which would implement a more realistic turning behaviour, as it would not happen instataneously, but rather with a smooth motion.

By allowing the `turtlesimAutomata` package to accept arguments on startup, the user could specify several parameters, such as the initial position of the turtle, the speed of the turtle, or the angle it shall turn when hitting a wall. These arguments may even be updated on runtime. This would make the package more versatile and user-friendly.

Bibliography

[1] *ROS 2 Documentation — ROS 2 Documentation: Humble documentation*. URL: https://docs.ros.org/en/humble/index.html (visited on 06/01/2024).

[2] *Introducing turtlesim and rqt — ROS 2 Documentation: Eloquent documentation*. URL: https://docs.ros.org/en/eloquent/Tutorials/Turtlesim/Introducing-Turtlesim.html (visited on 06/01/2024).

List of Figures

Appendix A

turtlesimAutomata source code

```cpp
#include "rclcpp/rclcpp.hpp"
#include "rcl_interfaces/msg/log.hpp"
#include "std_msgs/msg/float64.hpp"
#include "std_msgs/msg/bool.hpp"
#include <cstdlib> // Include the C standard library for random number generation

class StartTurtle : public rclcpp::Node
{
public:
    StartTurtle() : Node("start_turtle")
    {
        subscription_ = this->create_subscription<rcl_interfaces::msg::Log>(
            "/rosout", 10, std::bind(&StartTurtle::log_callback, this, std::placeholders::_1));

        angle_publisher_ = this->create_publisher<std_msgs::msg::Float64>("/turn_angle", 1);
        //drive_publisher_ = this->create_publisher<std_msgs::msg::Bool>("/drive_turtle", 1);

        RCLCPP_INFO(this->get_logger(), "Started 'start_turtle' node");
    }

private:
    void log_callback(const rcl_interfaces::msg::Log::SharedPtr msg)
    {
        if (msg->msg.find("Spawning turtle") != std::string::npos)
        {
            RCLCPP_INFO(this->get_logger(), "Detected 'Spawning turtle' message. Proceeding with actions.");
            std::this_thread::sleep_for(std::chrono::milliseconds(1500));
            publish_random_angle();
            //std::this_thread::sleep_for(std::chrono::
```

```
milliseconds(1500));
            //publish_drive_true();
            rclcpp::shutdown();
        }
    }

    void publish_random_angle()
    {
        // Generate a random angle in range of 45 to 90, 135 to
 180, 225 to 270, 315 to 360 degrees
        // this ensures, that the turtle can turn away from the
 wall with one 90 degree clockwise turn,
        // thus keeping the visuals interesting.
        // (all other angles result in the turtle just drawing
a straight line between two walls,
        // as it alsways ahs to perofrm 180 degree rotations)
        /*
        double angle_degrees = rand() % 45;
        int modifier = rand() % 4;
        angle_degrees *=  -1;
        angle_degrees += modifier * 90;
        */

        double angle_degrees = generate_random_angle();

        auto angle_msg = std_msgs::msg::Float64();
        angle_msg.data = angle_degrees;
        angle_publisher_->publish(angle_msg);

        RCLCPP_INFO(this->get_logger(), "Published random angle
: %.2f degrees", angle_msg.data);
    }

    void publish_drive_true()
    {
        auto drive_msg = std_msgs::msg::Bool();
        drive_msg.data = true;
        drive_publisher_->publish(drive_msg);

        RCLCPP_INFO(this->get_logger(), "Published 'true' to /
drive_turtle");
    }

    double generate_random_angle()
    {
        // Seed the random number generator
        srand(time(nullptr));

        // Define the ranges for each quadrant
        int lower_bounds[] = {45, 135, 225, 315};
        int upper_bounds[] = {90, 180, 270, 360};

        // Randomly select a quadrant
        int quadrant = rand() % 4;

        // Generate a random angle within the selected quadrant
        int angle = rand() % (upper_bounds[quadrant] -
```

```cpp
lower_bounds[quadrant] + 1) + lower_bounds[quadrant];

        return angle;
    }

    rclcpp::Subscription<rcl_interfaces::msg::Log>::SharedPtr subscription_;
    rclcpp::Publisher<std_msgs::msg::Float64>::SharedPtr angle_publisher_;
    rclcpp::Publisher<std_msgs::msg::Bool>::SharedPtr drive_publisher_;
};

int main(int argc, char *argv[])
{
    rclcpp::init(argc, argv);
    auto node = std::make_shared<StartTurtle>();
    rclcpp::spin(node);
    std::this_thread::sleep_for(std::chrono::seconds(5));
    rclcpp::shutdown();
    return 0;
}
```

Listing A.1. /start_turtle source code

```cpp
#include "rclcpp/rclcpp.hpp"
#include "std_msgs/msg/bool.hpp"
#include "geometry_msgs/msg/twist.hpp"

class DriveTurtleContinuously : public rclcpp::Node
{
public:
    DriveTurtleContinuously() : Node("drive_turtle_continuously"), drive_turtle_(false)
    {
        subscription_ = this->create_subscription<std_msgs::msg::Bool>(
            "/drive_turtle", 10, std::bind(&DriveTurtleContinuously::drive_callback, this, std::placeholders::_1));
        cmd_vel_publisher_ = this->create_publisher<geometry_msgs::msg::Twist>("turtle1/cmd_vel", 10);
        timer_ = this->create_wall_timer(
            std::chrono::milliseconds(100), std::bind(&DriveTurtleContinuously::publish_velocity, this));

        RCLCPP_INFO(this->get_logger(), "Started 'drive_turtle_continuously' node");
    }

private:
    void drive_callback(const std_msgs::msg::Bool::SharedPtr msg)
    {
        drive_turtle_ = msg->data;
        if (!drive_turtle_) {
            // Immediately stop the turtle
            auto stop_msg = geometry_msgs::msg::Twist();
            cmd_vel_publisher_->publish(stop_msg);
            RCLCPP_INFO(this->get_logger(), "Received stop command. Stopping turtle.");
        } else {
            RCLCPP_INFO(this->get_logger(), "Received drive command. Starting turtle.");
        }
    }

    void publish_velocity()
    {
        if (drive_turtle_)
        {
            auto twist_msg = geometry_msgs::msg::Twist();
            twist_msg.linear.x = 3.0;  // Set linear x velocity to 1.0
            cmd_vel_publisher_->publish(twist_msg);
            //RCLCPP_INFO(this->get_logger(), "Publishing cmd_vel to move turtle.");
        }
    }

    rclcpp::Subscription<std_msgs::msg::Bool>::SharedPtr subscription_;
    rclcpp::Publisher<geometry_msgs::msg::Twist>::SharedPtr cmd_vel_publisher_;
    rclcpp::TimerBase::SharedPtr timer_;
    bool drive_turtle_;
};

int main(int argc, char *argv[])
{
    rclcpp::init(argc, argv);
    auto node = std::make_shared<DriveTurtleContinuously>();
    rclcpp::spin(node);
    rclcpp::shutdown();
    return 0;
}
```

Listing A.2. /drive_turtle_continuously source code

```
#include "rclcpp/rclcpp.hpp"
#include "std_msgs/msg/float64.hpp"
#include "std_msgs/msg/bool.hpp"
#include "turtlesim/srv/teleport_relative.hpp"
#include "geometry_msgs/msg/twist.hpp"

class TurnTurtle : public rclcpp::Node
{
public:
    TurnTurtle() : Node("turn_turtle")
    {
        subscription_ = this->create_subscription<std_msgs::msg::Float64>(
            "/turn_angle", 1, std::bind(&TurnTurtle::angle_callback, this, std::placeholders::_1));
```

```cpp

        client_ = this->create_client<turtlesim::srv::TeleportRelative>("turtle1/teleport_relative");
        //cmd_vel_publisher_ = this->create_publisher<geometry_msgs::msg::Twist>("turtle1/cmd_vel", 1);
        drive_turtle_publisher_ = this->create_publisher<std_msgs::msg::Bool>("/drive_turtle", 1);

        RCLCPP_INFO(this->get_logger(), "Started 'turn_turtle' node");
    }

private:
    void angle_callback(const std_msgs::msg::Float64::SharedPtr msg)
    {
        double angle_degrees = msg->data;
        RCLCPP_INFO(this->get_logger(), "Received angle: %.2f degrees. Stopping and turning turtle.", angle_degrees);
        turn_turtle(angle_degrees);
    }

    void turn_turtle(double angle_degrees)
    {
        // Stop the turtle's current movement
        /*
        auto stop_message = geometry_msgs::msg::Twist();
        stop_message.linear.x = 0.0;
        stop_message.angular.z = 0.0;
        cmd_vel_publisher_->publish(stop_message);
        */
        rclcpp::sleep_for(std::chrono::seconds(1)); // Wait for a second to ensure it stops

        if (!client_->wait_for_service(std::chrono::seconds(1))) {
            RCLCPP_ERROR(this->get_logger(), "Service not available. Make sure the turtlesim node is running.");
            return;
        }

        auto request = std::make_shared<turtlesim::srv::TeleportRelative::Request>();
        request->linear = 0.0;
        request->angular = angle_degrees * (M_PI / 180.0); // Convert degrees to radians

        auto result = client_->async_send_request(request);
        // Don't wait for the service to respond! It does not.

        // Notify that the turning is finished
        auto drive_message = std_msgs::msg::Bool();
        drive_message.data = true;
        rclcpp::sleep_for(std::chrono::seconds(1));
        drive_turtle_publisher_->publish(drive_message);
    }

```

```
        rclcpp::Subscription<std_msgs::msg::Float64>::SharedPtr subscription_;
        rclcpp::Client<turtlesim::srv::TeleportRelative>::SharedPtr client_;
        rclcpp::Publisher<geometry_msgs::msg::Twist>::SharedPtr cmd_vel_publisher_;
        rclcpp::Publisher<std_msgs::msg::Bool>::SharedPtr drive_turtle_publisher_;
    };

    int main(int argc, char *argv[])
    {
        rclcpp::init(argc, argv);
        auto node = std::make_shared<TurnTurtle>();
        rclcpp::spin(node);
        rclcpp::shutdown();
        return 0;
    }
```

Listing A.3. /turn_turtle source code

```
#include "rclcpp/rclcpp.hpp"
#include "rcl_interfaces/msg/log.hpp"
#include "std_msgs/msg/float64.hpp"
#include "std_msgs/msg/bool.hpp"

class Edge : public rclcpp::Node
{
public:
    Edge() : Node("edge"), should_look_for_edges_(false)
    {
        drive_turtle_subscription_ = this->create_subscription<std_msgs::msg::Bool>(
            "/drive_turtle", 1, std::bind(&Edge::drive_turtle_callback, this, std::placeholders::_1));
        turn_angle_publisher_ = this->create_publisher<std_msgs::msg::Float64>("/turn_angle", 1);
        drive_turtle_publisher_ = this->create_publisher<std_msgs::msg::Bool>("/drive_turtle", 1);

        RCLCPP_INFO(this->get_logger(), "Started 'edge' node");
    }

private:
    void subscribe_to_rosout()
    {
        rosout_subscription_ = this->create_subscription<rcl_interfaces::msg::Log>(
            "/rosout", 1, std::bind(&Edge::listener_callback, this, std::placeholders::_1));
    }

    void drive_turtle_callback(const std_msgs::msg::Bool::SharedPtr msg)
    {
        should_look_for_edges_ = msg->data;
        if (should_look_for_edges_)
        {
            RCLCPP_INFO(this->get_logger(), "Received true on /
drive_turtle. Subscribing to /rosout for edge detection.");
            subscribe_to_rosout();
        }
        else
        {
            RCLCPP_INFO(this->get_logger(), "Received false on /
drive_turtle. Unsubscribing from /rosout.");
            rosout_subscription_.reset();
        }
    }

    void listener_callback(const rcl_interfaces::msg::Log::
SharedPtr msg)
    {
        if (should_look_for_edges_ && msg->msg.find("Oh no! I hit
the wall!") != std::string::npos)
        {
            RCLCPP_INFO(this->get_logger(), "Received message: 'Oh
no! I hit the wall!'. Publishing angle and stopping turtle...")
;
            publish_drive_turtle(false);
            publish_turn_angle();
            // Unsubscribing from /rosout for 5 milliseconds to
avoid multiple wall-hitting messages
            /**/
            rosout_subscription_.reset();
            std::this_thread::sleep_for(std::chrono::milliseconds
(50));
            //subscribe_to_rosout();
        }
    }

    void publish_turn_angle()
    {
        auto message = std_msgs::msg::Float64();
        message.data = -90.0; // 90 degrees clockwise
        turn_angle_publisher_->publish(message);
    }

    void publish_drive_turtle(bool data)
    {
        auto message = std_msgs::msg::Bool();
        message.data = data;
        drive_turtle_publisher_->publish(message);
    }

    rclcpp::Subscription<rcl_interfaces::msg::Log>::SharedPtr
rosout_subscription_;
    rclcpp::Subscription<std_msgs::msg::Bool>::SharedPtr
drive_turtle_subscription_;
    rclcpp::Publisher<std_msgs::msg::Float64>::SharedPtr
turn_angle_publisher_;
    rclcpp::Publisher<std_msgs::msg::Bool>::SharedPtr
drive_turtle_publisher_;
    bool should_look_for_edges_;
```

```
};

int main(int argc, char *argv[])
{
    rclcpp::init(argc, argv);
    auto node = std::make_shared<Edge>();
    rclcpp::spin(node);
    rclcpp::shutdown();
    return 0;
}
```

Listing A.4. /edge source code

Appendix B

Auxiliary files

```

cmake_minimum_required(VERSION 3.8)
project(turtlesimAutomata)

if(CMAKE_COMPILER_IS_GNUCXX OR CMAKE_CXX_COMPILER_ID MATCHES "Clang")
  add_compile_options(-Wall -Wextra -Wpedantic)
endif()

# find dependencies
find_package(ament_cmake REQUIRED)
# uncomment the following section in order to fill in
# further dependencies manually.
# find_package(<dependency> REQUIRED)
find_package(rclcpp REQUIRED)
find_package(std_msgs REQUIRED)
#find_package(rosidl_default_generators REQUIRED)
#find_package(turtlesimAutomata REQUIRED)
find_package(turtlesim REQUIRED)
find_package(geometry_msgs REQUIRED)
find_package(rcl_interfaces)


#rosidl_generate_interfaces(${PROJECT_NAME}
#  "srv/acknowledge.srv"
#  DEPENDENCIES std_msgs
#)

# Include directories
include_directories(include)



add_executable(edge src/edge.cpp)
ament_target_dependencies(edge rclcpp std_msgs)
#  $<BUILD_INTERFACE:${CMAKE_CURRENT_SOURCE_DIR}/include>
#  $<INSTALL_INTERFACE:include>)
#target_compile_features(edge PUBLIC c_std_99 cxx_std_17)  # Require C99 and C++17
```

```

    add_executable(turn_turtle src/turn_turtle.cpp)
    ament_target_dependencies(turn_turtle rclcpp std_msgs turtlesim geometry_msgs)

    add_executable(drive_turtle_continuously src/drive_turtle_continuously.cpp)
    ament_target_dependencies(drive_turtle_continuously std_msgs rclcpp geometry_msgs)

    add_executable(start_turtle src/start_turtle.cpp)
    ament_target_dependencies(start_turtle std_msgs rclcpp rcl_interfaces)
    target_include_directories(turn_turtle PUBLIC
      $<BUILD_INTERFACE:${CMAKE_CURRENT_SOURCE_DIR}/include>
      $<INSTALL_INTERFACE:include>)
    target_compile_features(turn_turtle PUBLIC c_std_99 cxx_std_17)  # Require C99 and C++17


    install(TARGETS
      edge
      turn_turtle
      drive_turtle_continuously
      start_turtle

      DESTINATION lib/${PROJECT_NAME})


    #this is important for the launchfile to be accesible from the ros2_ws
    install(DIRECTORY launch
    DESTINATION share/${PROJECT_NAME})



    if(BUILD_TESTING)
      find_package(ament_lint_auto REQUIRED)
      # the following line skips the linter which checks for copyrights
      # comment the line when a copyright and license is added to all source files
      set(ament_cmake_copyright_FOUND TRUE)
      # the following line skips cpplint (only works in a git repo)
      # comment the line when this package is in a git repo and when
      # a copyright and license is added to all source files
      set(ament_cmake_cpplint_FOUND TRUE)
      ament_lint_auto_find_test_dependencies()
    endif()

    ament_package()
```

Listing B.1. CMakeLists.txt

```
    <?xml version="1.0"?>
<?xml-model href="http://download.ros.org/schema/package_format3.
```

```
   xsd" schematypens="http://www.w3.org/2001/XMLSchema"?>
<package format="3">
  <name>turtlesimAutomata</name>
  <version>0.0.0</version>
  <description>TODO: Package description</description>
  <maintainer email="jakobspindler@gmx.at">jakob</maintainer>
  <license>Apache-2.0</license>

  <!--depend>std_msgs</depend>
  <buildtool_depend>rosidl_default_generators</buildtool_depend>
  <exec_depend>rosidl_default_runtime</exec_depend>
  <member_of_group>rosidl_interface_packages</member_of_group-->

  <buildtool_depend>ament_cmake</buildtool_depend>

  <depend>rclcpp</depend>
  <depend>std_msgs</depend>
  <depend>turtlesim</depend>
  <depend>geometry_msgs</depend>
  <depend>rcl_interfaces</depend>



  <test_depend>ament_lint_auto</test_depend>
  <test_depend>ament_lint_common</test_depend>

  <exec_depend>ros2launch</exec_depend>

  <export>
    <build_type>ament_cmake</build_type>
  </export>
</package>
```

Listing B.2. Package.xml

```
    <launch>
    <!-- Launch the drive_turtle_continuously node -->
    <node pkg="turtlesimAutomata" exec="drive_turtle_continuously"
   name="drive_turtle_continuously" output="screen"/>

    <!-- Launch the edge node -->
    <node pkg="turtlesimAutomata" exec="edge" name="edge" output="
   screen"/>

    <!-- Launch the turn_turtle node -->
    <node pkg="turtlesimAutomata" exec="turn_turtle" name="
   turn_turtle" output="screen"/>

    <!-- Launch the start_turtle node -->
    <node pkg="turtlesimAutomata" exec="start_turtle" name="
   start_turtle" output="screen"/>

    <!-- Launch the turtlesim node -->
    <node pkg="turtlesim" exec="turtlesim_node" name="
   turtlesim_node" output="screen"/>
  </launch>
```

Listing B.3. turtlesimAutomata_launch.xml