

# Appendix: An Empirical Study of Behavior Trees in Robotics

## 1 Appendix Contents

In this appendix we provide a brief description of the studied projects in the paper, in addition to supporting materials to inspire the community to use and further develop our work in behavior trees. The followings describe the content of our appendix:

- GitHub mined projects description that was derived from their constructed behavior trees models (provided in section 2 in this document).
- Mining GitHub results dis-aggregated by behavior trees languages with url to each project GitHub file location containing the mining terms explained in section 3.2 in the paper (provided in projects\_all.xlsx file)
- The raw data for former projects' behavior trees models (provided in //raw\_model\_data Folder dis-aggregated by behavior trees languages).
- Python jupyter notebooks for mining GitHub and extracting number of composite nodes (provided in //scripts Folder).
- Higher resolution images for behavior trees models in the paper (Figure 3, 5). In addition to other projects models (provided in //BT\_models\_visualization Folder).
- The extracted statistic from the studied behavior trees models per model, e.g. number of Sequence in models. (provided in //raw\_model\_data/BehaviorTree.CPP/BehaviorTree\_CPP\_codes\_analysis.xlsx and //raw\_model\_data/py\_trees\_ros/py\_trees\_ros\_codes\_analysis.xlsx)

## 2 Subject Projects

We identified 13 robotic projects that have 37 BT models. Table 5 in the main paper provides an overview of these projects. In the following paragraph we provide a brief description of those projects, which was derived from our constructed BT models for each project.

- Smarc\_missions: belongs to Swedish Maritime Robotics Center (SMaRC) in collaboration with PhD students at KTH Royal Institute of Technology. The goal of this project is to test submarine hardware by specifying a tree with specific check points.

According to one of project contributors the reasons for using BT in this project were the following: 1. easy to build and modify, especially during the live test of the submarine due to BTs modularity characteristic and ROS visualization integration. 2. Neptus integration with ROS using BTs.

- sam\_march: belongs to a PhD student who is one of the collaborators in SMaRC project. Its goal and BT model are exactly the same as SMaRC project, with minor changes in the composite node types.

- stardust: belongs to a team in France that participated in the french robotics contest Eurobot<sup>1</sup> for picking, sorting, weighing pucks in Atom Factory<sup>2</sup>.
- dyno: belongs to a Swedish start up called Dyno Robotics<sup>3</sup>. This project models behavior for parcel delivery drone. It has two BT models one for parcel delivery and the other for drone root scheduler.
- gizmo: in this project a talking robot performs moving and talking tasks if activated. BT models start with a check if robot activated then performs a sequence of sub-tasks, like moving to the center of a stage.
- robots\_project: belongs to a student or researcher in Harbin Institute of Technology, Shenzhen. We think the robot participated in DJI RoboMaster AI Challenge<sup>4</sup>. The robot performs different tasks depending on the environment status (Selector is used in the root node child). In general the robot is a patrol robot that performs multiple tasks like check for bullets supply or search a region for enemies.
- refills\_second\_review: related to refills EU project<sup>5</sup> where robots are used for shelf refilling. The robot starts by navigating to a shelf, detecting shelf ID, then moving robot arm according to a given trajectory.
- mecatro-P17: belongs to a student or researcher in Mines ParisTech. This project contains 11 BT models for different robots (in the code developers distinguish between different robot sizes and colors). Robot performs different sequential tasks on a barrel, like moving to barrel position, placing items in a barrel and weighing barrel.
- robotics-player: belongs to a researcher in Vienna University of Technology. This is a navigation robot that explores areas and build their maps and it can avoid obstacles in its way.
- hans-ros-supervisor: belongs to Knowledge Media Institute<sup>6</sup>. Even though the BT model is not complete, e.g., empty action nodes, we decided to keep it in case developers decide to re-maintain it, especially this project concerns health and safety robot inspector, which is a hot-topic nowadays with the pandemic.
- smart\_cage\_architecture: belongs to Janelia Experimental Technology. The goal of this project is to create a SmartCage system which allows mice to perform voluntary head-fixations in their home cages to facilitate behavior training and experiments without human supervision. The current defined mission performs a sequence of checks, e.g. if a cage is open, if a mouse in tunnel module, checking mouse headbar, etc.
- mobile\_robot\_project: this project is a pick-and-place cube robot that can navigate to cube table.
- Robotics-Behaviour-Planning: this robot performs sequential tasks for moving to different positions and changing its arm and head direction.

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<sup>1</sup><https://www.eurobot.org/eurobot/eurobot-2019>

<sup>2</sup>More information about mission can be found here: <https://www.eurobot.org/eurobot/eurobot-2019>

<sup>3</sup><https://dynorobotics.se/>

<sup>4</sup><https://icra2019.org/competitions/dji-robomaster-ai-challenge>

<sup>5</sup><http://www.refills-project.eu/>

<sup>6</sup><https://robots.kmi.open.ac.uk/>