# Putting ChoiRbot to the Test

SWARM 2025

**PRESENTED BY Santiago Bernheim, Alejandro Ojeda, Nishant Pushparaju and Vivekananda Mattam**

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# What is ChoiRbot anyway?

Introduction

01

NYU

# ChoiRbot origin

- Swarm robotics framework designed for the simulation and testing of swarm behavior in robotic systems.
- Purpose:
  - Facilitate distributed optimization, control, and communication among autonomous robotic agents.
- Developed by OPT4Smart lab in University of Bolognia

*Source: A. Testa, A. Camisa, G. Notarstefano*, ChoiRbot: A ROS 2 toolbox for cooperative robotics, IEEE Robotics and Automation Letters, 6(2), 2714-2720, 2021

# ChoirBot Capabilities

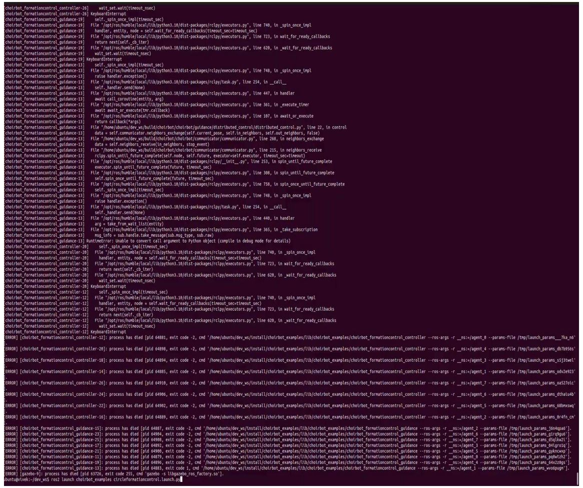
02

NYU

# ChoiRbot Framework overview

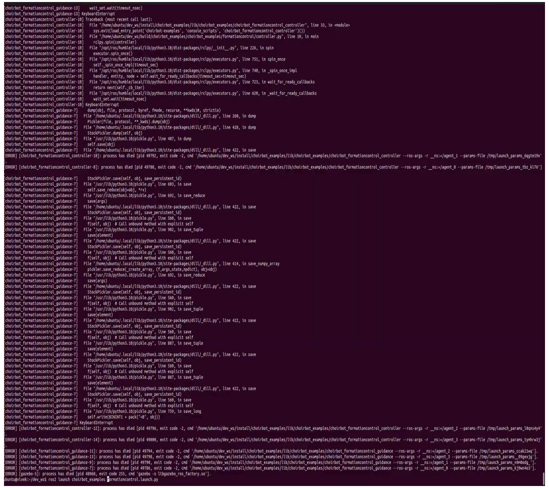
- **Distributed Optimization:**
  - Encodes advanced algorithms for efficient task distribution.
- **Peer-to-Peer Communication simulation:**
  - Supports seamless interactions among individual nodes.
- **Key Features:**
  - Formation Control: Maintaining specific formations.
  - Dynamic Task Assignment: Adapting tasks based on real-time conditions.

# ChoiRbot Formation control



```
[choirbot_formationcontrol_controller-26]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-26] KeyboardInterrupt
[choirbot_formationcontrol_guidance-19]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_guidance-19]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_guidance-19]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_guidance-19]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_guidance-19]     return next(self._cb_iter)
[choirbot_formationcontrol_guidance-19]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_guidance-19]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_guidance-19] KeyboardInterrupt
[choirbot_formationcontrol_guidance-13]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 748, in _spin_once_impl
[choirbot_formationcontrol_guidance-13]     raise handler.exception()
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/task.py", line 254, in __call__
[choirbot_formationcontrol_guidance-13]     self._handler.send(None)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 447, in handler
[choirbot_formationcontrol_guidance-13]     await call_coroutine(entity, arg)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 361, in _execute_timer
[choirbot_formationcontrol_guidance-13]     await await_or_execute(tmr.callback)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 107, in await_or_execute
[choirbot_formationcontrol_guidance-13]     return callback(*args)
[choirbot_formationcontrol_guidance-13]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/guidance/distributed_control/distributed_control.py", line 22, in control
[choirbot_formationcontrol_guidance-13]     data = self.communicator.neighbors_exchange(self.current_pose, self.in_neighbors, self.out_neighbors, False)
[choirbot_formationcontrol_guidance-13]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/communicator/communicator.py", line 268, in neighbors_exchange
[choirbot_formationcontrol_guidance-13]     data = self.neighbors_receive(in_neighbors, stop_event)
[choirbot_formationcontrol_guidance-13]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/communicator/communicator.py", line 215, in neighbors_receive
[choirbot_formationcontrol_guidance-13]     rclpy.spin_until_future_complete(self.node, self.future, executor=self.executor, timeout_sec=timeout)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/__init__.py", line 253, in spin_until_future_complete
[choirbot_formationcontrol_guidance-13]     executor.spin_until_future_complete(future, timeout_sec)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 308, in spin_until_future_complete
[choirbot_formationcontrol_guidance-13]     self.spin_once_until_future_complete(future, timeout_sec)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 758, in spin_once_until_future_complete
[choirbot_formationcontrol_guidance-13]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 748, in _spin_once_impl
[choirbot_formationcontrol_guidance-13]     raise handler.exception()
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/task.py", line 254, in __call__
[choirbot_formationcontrol_guidance-13]     self._handler.send(None)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 440, in handler
[choirbot_formationcontrol_guidance-13]     arg = take_from_wait_list(entity)
[choirbot_formationcontrol_guidance-13]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 365, in _take_subscription
[choirbot_formationcontrol_guidance-13]     msg_info = sub.handle.take_message(sub.msg_type, sub.raw)
[choirbot_formationcontrol_guidance-13] RuntimeError: Unable to convert call argument to Python object (compile in debug mode for details)
[choirbot_formationcontrol_controller-20]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_controller-20]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_controller-20]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_controller-20]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_controller-20]     return next(self._cb_iter)
[choirbot_formationcontrol_controller-20]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_controller-20]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-20] KeyboardInterrupt
[choirbot_formationcontrol_controller-12]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_controller-12]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_controller-12]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_controller-12]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_controller-12]     return next(self._cb_iter)
[choirbot_formationcontrol_controller-12]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_controller-12]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-12] KeyboardInterrupt
[ERROR] [choirbot_formationcontrol_controller-12]: process has died [pid 64881, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params___7ka_n6'
].
[ERROR] [choirbot_formationcontrol_controller-20]: process has died [pid 64898, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_4 --params-file /tmp/launch_params_db7b956s'
].
[ERROR] [choirbot_formationcontrol_controller-18]: process has died [pid 64894, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params_s5j3twel'
].
[ERROR] [choirbot_formationcontrol_controller-14]: process has died [pid 64885, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_odv2e923'
].
[ERROR] [choirbot_formationcontrol_controller-26]: process has died [pid 64910, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_7 --params-file /tmp/launch_params_oa527oic'
].
[ERROR] [choirbot_formationcontrol_controller-24]: process has died [pid 64906, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_6 --params-file /tmp/launch_params_dthaiu4b'
].
[ERROR] [choirbot_formationcontrol_controller-22]: process has died [pid 64902, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_5 --params-file /tmp/launch_params_68bmxswq'
].
[ERROR] [choirbot_formationcontrol_controller-16]: process has died [pid 64889, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_0r4fn_cm'
].
[ERROR] [choirbot_formationcontrol_guidance-15]: process has died [pid 64887, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_j6n4qpa6'].
[ERROR] [choirbot_formationcontrol_guidance-23]: process has died [pid 64904, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_6 --params-file /tmp/launch_params_g1rq9gu6'].
[ERROR] [choirbot_formationcontrol_guidance-25]: process has died [pid 64908, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_7 --params-file /tmp/launch_params_d5qlkw2l'].
[ERROR] [choirbot_formationcontrol_guidance-17]: process has died [pid 64892, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params_04lgro1q'].
[ERROR] [choirbot_formationcontrol_guidance-21]: process has died [pid 64900, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_5 --params-file /tmp/launch_params_gykncwxp'].
[ERROR] [choirbot_formationcontrol_guidance-11]: process has died [pid 64879, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params_pq0wtzh2'].
[ERROR] [choirbot_formationcontrol_guidance-19]: process has died [pid 64896, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_4 --params-file /tmp/launch_params_64x2z0gs'].
[ERROR] [choirbot_formationcontrol_guidance-13]: process has died [pid 64883, exit code 1, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_wvo6pugm'].
[ERROR] [gazebo-9]: process has died [pid 63726, exit code 255, cmd 'gazebo -s libgazebo_ros_factory.so'].
ubuntu@vivek:~/dev_ws$ ros2 launch choirbot_examples circleformationcontrol.launch.py
```

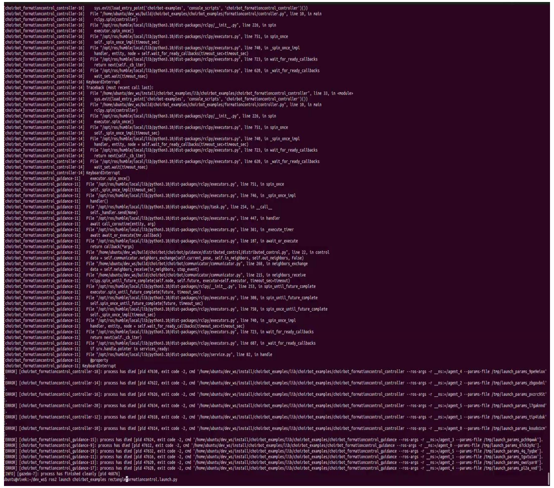
Circle : 8 Turtlebots



```
[choirbot_formationcontrol_guidance-13]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_guidance-13] KeyboardInterrupt
[choirbot_formationcontrol_controller-10] Traceback (most recent call last):
[choirbot_formationcontrol_controller-10]   File "/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller", line 33, in <module>
[choirbot_formationcontrol_controller-10]     sys.exit(load_entry_point('choirbot-examples', 'console_scripts', 'choirbot_formationcontrol_controller')())
[choirbot_formationcontrol_controller-10]   File "/home/ubuntu/dev_ws/build/choirbot_examples/choirbot_examples/formationcontrol/controller.py", line 10, in main
[choirbot_formationcontrol_controller-10]     rclpy.spin(controller)
[choirbot_formationcontrol_controller-10]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/__init__.py", line 226, in spin
[choirbot_formationcontrol_controller-10]     executor.spin_once()
[choirbot_formationcontrol_controller-10]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 751, in spin_once
[choirbot_formationcontrol_controller-10]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_controller-10]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_controller-10]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_controller-10]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_controller-10]     return next(self._cb_iter)
[choirbot_formationcontrol_controller-10]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_controller-10]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-10] KeyboardInterrupt
[choirbot_formationcontrol_guidance-7]     dump(obj, file, protocol, byref, fmode, recurse, **kwds)#, strictio)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 260, in dump
[choirbot_formationcontrol_guidance-7]     Pickler(file, protocol, **_kwds).dump(obj)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 428, in dump
[choirbot_formationcontrol_guidance-7]     StockPickler.dump(self, obj)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 487, in dump
[choirbot_formationcontrol_guidance-7]     self.save(obj)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[ERROR] [choirbot_formationcontrol_controller-10]: process has died [pid 49792, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_6qgte19x'
].
[ERROR] [choirbot_formationcontrol_controller-8]: process has died [pid 49788, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params_tbz_kl76']

[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 603, in save
[choirbot_formationcontrol_guidance-7]     self.save_reduce(obj=obj, *rv)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 692, in save_reduce
[choirbot_formationcontrol_guidance-7]     save(args)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 902, in save_tuple
[choirbot_formationcontrol_guidance-7]     save(element)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 414, in save_numpy_array
[choirbot_formationcontrol_guidance-7]     pickler.save_reduce(_create_array, (f,args,state,npdict), obj=obj)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 692, in save_reduce
[choirbot_formationcontrol_guidance-7]     save(args)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 902, in save_tuple
[choirbot_formationcontrol_guidance-7]     save(element)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 887, in save_tuple
[choirbot_formationcontrol_guidance-7]     save(element)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 887, in save_tuple
[choirbot_formationcontrol_guidance-7]     save(element)
[choirbot_formationcontrol_guidance-7]   File "/home/ubuntu/.local/lib/python3.10/site-packages/dill/_dill.py", line 422, in save
[choirbot_formationcontrol_guidance-7]     StockPickler.save(self, obj, save_persistent_id)
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 560, in save
[choirbot_formationcontrol_guidance-7]     f(self, obj)  # Call unbound method with explicit self
[choirbot_formationcontrol_guidance-7]   File "/usr/lib/python3.10/pickle.py", line 759, in save_long
[choirbot_formationcontrol_guidance-7]     self.write(BININT1 + pack("<B", obj))
[choirbot_formationcontrol_guidance-7] KeyboardInterrupt
[ERROR] [choirbot_formationcontrol_controller-12]: process has died [pid 49796, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_l0qns4y4'
].
[ERROR] [choirbot_formationcontrol_controller-14]: process has died [pid 49800, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params_tymhrw3j'
].
[ERROR] [choirbot_formationcontrol_guidance-11]: process has died [pid 49794, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_ccak21wq'].
[ERROR] [choirbot_formationcontrol_guidance-13]: process has died [pid 49798, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params__09gexjg'].
[ERROR] [choirbot_formationcontrol_guidance-9]: process has died [pid 49790, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_n9m0odg_'].
[ERROR] [choirbot_formationcontrol_guidance-7]: process has died [pid 49786, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params_kj9wn4o3'].
[ERROR] [gazebo-5]: process has died [pid 48968, exit code 255, cmd 'gazebo -s libgazebo_ros_factory.so'].
ubuntu@vivek:~/dev_ws$ ros2 launch choirbot_examples formationcontrol.launch.py
```

Hexagon : 6 Turtlebots

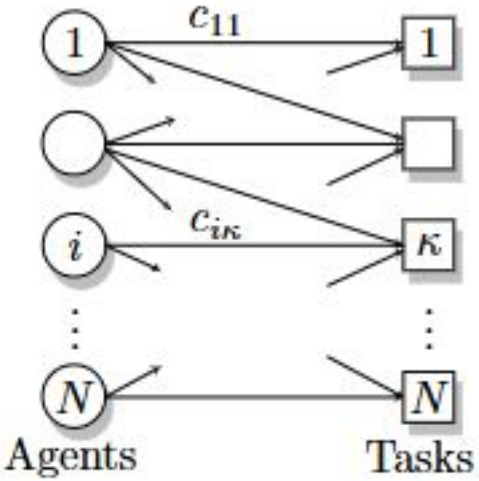


```
[choirbot_formationcontrol_controller-16]     sys.exit(load_entry_point('choirbot-examples', 'console_scripts', 'choirbot_formationcontrol_controller')())
[choirbot_formationcontrol_controller-16]   File "/home/ubuntu/dev_ws/build/choirbot_examples/choirbot_examples/formationcontrol/controller.py", line 10, in main
[choirbot_formationcontrol_controller-16]     rclpy.spin(controller)
[choirbot_formationcontrol_controller-16]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/__init__.py", line 226, in spin
[choirbot_formationcontrol_controller-16]     executor.spin_once()
[choirbot_formationcontrol_controller-16]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 751, in spin_once
[choirbot_formationcontrol_controller-16]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_controller-16]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_controller-16]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_controller-16]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_controller-16]     return next(self._cb_iter)
[choirbot_formationcontrol_controller-16]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_controller-16]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-16] KeyboardInterrupt
[choirbot_formationcontrol_controller-14] Traceback (most recent call last):
[choirbot_formationcontrol_controller-14]   File "/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller", line 33, in <module>
[choirbot_formationcontrol_controller-14]     sys.exit(load_entry_point('choirbot-examples', 'console_scripts', 'choirbot_formationcontrol_controller')())
[choirbot_formationcontrol_controller-14]   File "/home/ubuntu/dev_ws/build/choirbot_examples/choirbot_examples/formationcontrol/controller.py", line 10, in main
[choirbot_formationcontrol_controller-14]     rclpy.spin(controller)
[choirbot_formationcontrol_controller-14]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/__init__.py", line 226, in spin
[choirbot_formationcontrol_controller-14]     executor.spin_once()
[choirbot_formationcontrol_controller-14]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 751, in spin_once
[choirbot_formationcontrol_controller-14]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_controller-14]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_controller-14]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_controller-14]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_controller-14]     return next(self._cb_iter)
[choirbot_formationcontrol_controller-14]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 620, in _wait_for_ready_callbacks
[choirbot_formationcontrol_controller-14]     wait_set.wait(timeout_nsec)
[choirbot_formationcontrol_controller-14] KeyboardInterrupt
[choirbot_formationcontrol_guidance-11]     executor.spin_once()
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 751, in spin_once
[choirbot_formationcontrol_guidance-11]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 746, in _spin_once_impl
[choirbot_formationcontrol_guidance-11]     handler()
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/task.py", line 254, in __call__
[choirbot_formationcontrol_guidance-11]     self._handler.send(None)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 447, in handler
[choirbot_formationcontrol_guidance-11]     await call_coroutine(entity, arg)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 361, in _execute_timer
[choirbot_formationcontrol_guidance-11]     await await_or_execute(tmr.callback)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 107, in await_or_execute
[choirbot_formationcontrol_guidance-11]     return callback(*args)
[choirbot_formationcontrol_guidance-11]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/guidance/distributed_control/distributed_control.py", line 22, in control
[choirbot_formationcontrol_guidance-11]     data = self.communicator.neighbors_exchange(self.current_pose, self.in_neighbors, self.out_neighbors, False)
[choirbot_formationcontrol_guidance-11]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/communicator/communicator.py", line 268, in neighbors_exchange
[choirbot_formationcontrol_guidance-11]     data = self.neighbors_receive(in_neighbors, stop_event)
[choirbot_formationcontrol_guidance-11]   File "/home/ubuntu/dev_ws/build/choirbot/choirbot/communicator/communicator.py", line 215, in neighbors_receive
[choirbot_formationcontrol_guidance-11]     rclpy.spin_until_future_complete(self.node, self.future, executor=self.executor, timeout_sec=timeout)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/__init__.py", line 253, in spin_until_future_complete
[choirbot_formationcontrol_guidance-11]     executor.spin_until_future_complete(future, timeout_sec)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 308, in spin_until_future_complete
[choirbot_formationcontrol_guidance-11]     self.spin_once_until_future_complete(future, timeout_sec)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 758, in spin_once_until_future_complete
[choirbot_formationcontrol_guidance-11]     self._spin_once_impl(timeout_sec)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 740, in _spin_once_impl
[choirbot_formationcontrol_guidance-11]     handler, entity, node = self.wait_for_ready_callbacks(timeout_sec=timeout_sec)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 723, in wait_for_ready_callbacks
[choirbot_formationcontrol_guidance-11]     return next(self._cb_iter)
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executors.py", line 687, in _wait_for_ready_callbacks
[choirbot_formationcontrol_guidance-11]     if srv.handle.pointer in services_ready:
[choirbot_formationcontrol_guidance-11]   File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/service.py", line 82, in handle
[choirbot_formationcontrol_guidance-11]     @property
[choirbot_formationcontrol_guidance-11] KeyboardInterrupt
[ERROR] [choirbot_formationcontrol_controller-18]: process has died [pid 47630, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_4 --params-file /tmp/launch_params_9pe9eiox'
].
[ERROR] [choirbot_formationcontrol_controller-14]: process has died [pid 47622, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_zbgovbnl'
].
[ERROR] [choirbot_formationcontrol_controller-16]: process has died [pid 47626, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params_pvzrc95t'
].
[ERROR] [choirbot_formationcontrol_controller-20]: process has died [pid 47634, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_5 --params-file /tmp/launch_params_l7gaknnd'
].
[ERROR] [choirbot_formationcontrol_controller-12]: process has died [pid 47618, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_tip4lduk'
].
[ERROR] [choirbot_formationcontrol_controller-10]: process has died [pid 47614, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_controller --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params_koudo1cm'
].
[ERROR] [choirbot_formationcontrol_guidance-15]: process has died [pid 47624, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_3 --params-file /tmp/launch_params_pch9qwwk'].
[ERROR] [choirbot_formationcontrol_guidance-9]: process has died [pid 47612, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_0 --params-file /tmp/launch_params_67ck3y9z'].
[ERROR] [choirbot_formationcontrol_guidance-19]: process has died [pid 47632, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_5 --params-file /tmp/launch_params_4q_7yqbe'].
[ERROR] [choirbot_formationcontrol_guidance-11]: process has died [pid 47616, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_1 --params-file /tmp/launch_params_tgxtu1ao'].
[ERROR] [choirbot_formationcontrol_guidance-13]: process has died [pid 47620, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_2 --params-file /tmp/launch_params_owoiyar0'].
[ERROR] [choirbot_formationcontrol_guidance-17]: process has died [pid 47628, exit code -2, cmd '/home/ubuntu/dev_ws/install/choirbot_examples/lib/choirbot_examples/choirbot_formationcontrol_guidance --ros-args -r __ns:=/agent_4 --params-file /tmp/launch_params_pl2a_vxd'].
[INFO] [gazebo-7]: process has finished cleanly [pid 46876]
ubuntu@vivek:~/dev_ws$ ros2 launch choirbot_examples rectangleformationcontrol.launch.py
```

Rectangle : 4 Turtlebots

# Dynamic Task assignment explained

- **Functionality:**
  - Robots dynamically allocate tasks to optimize performance and efficiency.
- **Benefits:**
  - Enhances adaptability and robustness in changing environments, crucial for real-world applications.



*Bürger, M., Notarstefano, G., Bullo, F., & Allgöwer, F. (2012). A distributed simplex algorithm for degenerate linear programs and multi-agent assignments. Automatica, 48(9), 2298-2304.*

# Our Implementation

03

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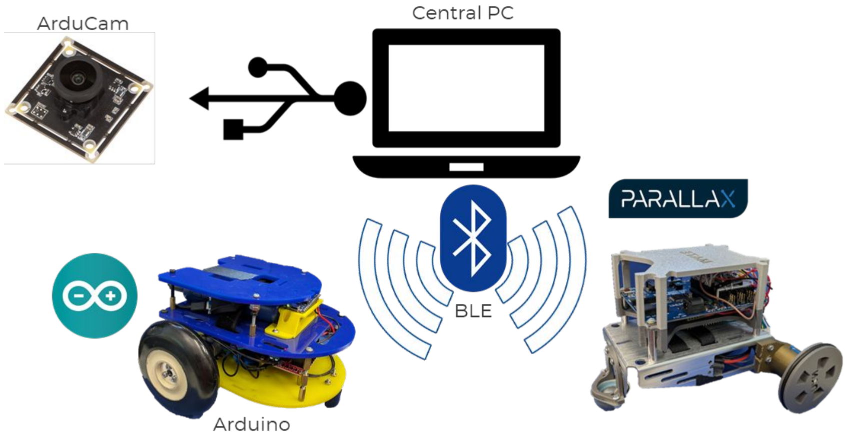
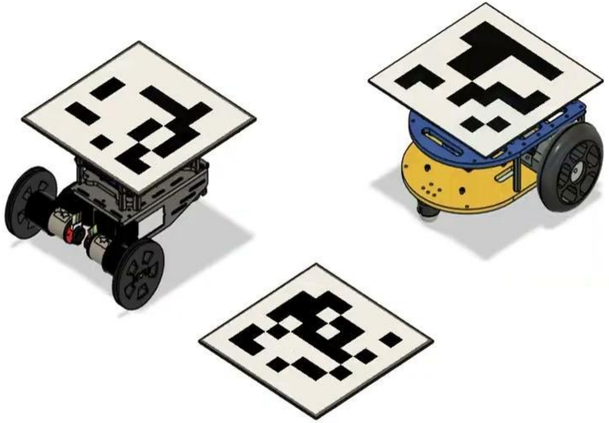
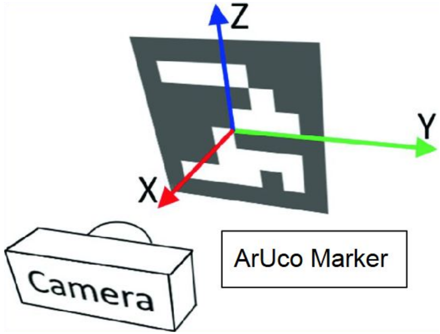
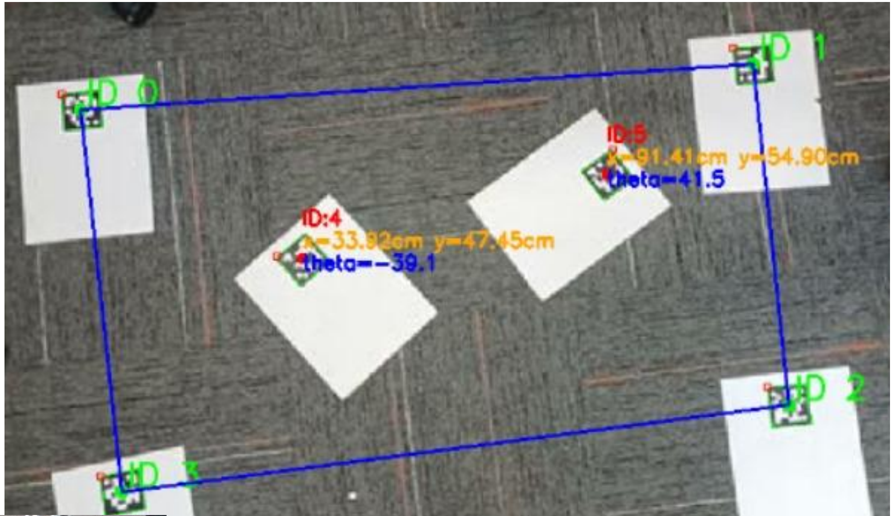
# Robots HW description

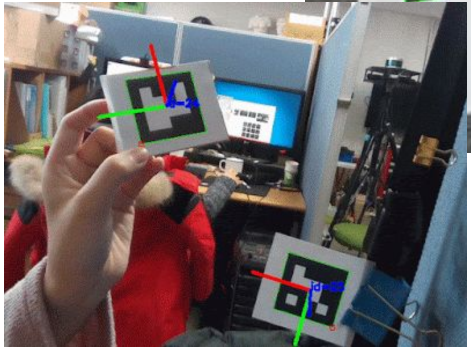




# Aruco Detector







# BLE Bridge

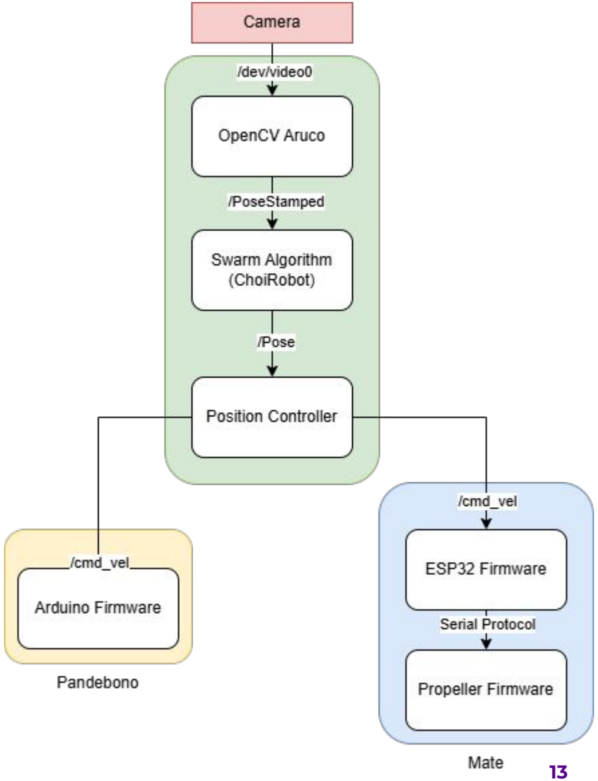
- **Functionality:**
  - Converts cmd_vel messages into BLE format for robot communication.
- **Connection Management:**
  - Identifies each robot via BLE MAC and ensures persistent connections with auto-reconnect capabilities.
- **Message Pipeline:**
  - Channels commands through a dedicated BLE service.

# System tweaks

| Component | Tweaks Made |
|---|---|
| Launch System | Removed randomness; added ArUco, GUI, Gazebo. |
| ArUco Integration and GUI | Markers 4 & 5 publish /agent_X/odom. |
| Initialization | Robots use ArUco-based pose startup. |
| Control Logic | Upgraded to unicycle feedback control. |
| BLE Handling | ble_bridge.py sends /cmd_vel to real bots. |

# Changes overview

- **Aruco_detector.py:**
  - Utilizes camera inputs for accurate positioning through ArUco marker detection.
- **Ble_bridge.py:**
  - Converts cmd_vel messages into Bluetooth Low Energy (BLE) signals for communication with the robots.
- **ROS2 Launcher:**
  - Integrates simulation and real-world operations seamlessly.
- **Robot Firmware:**
  - Translates velocity commands to motor speeds through BLE connections.



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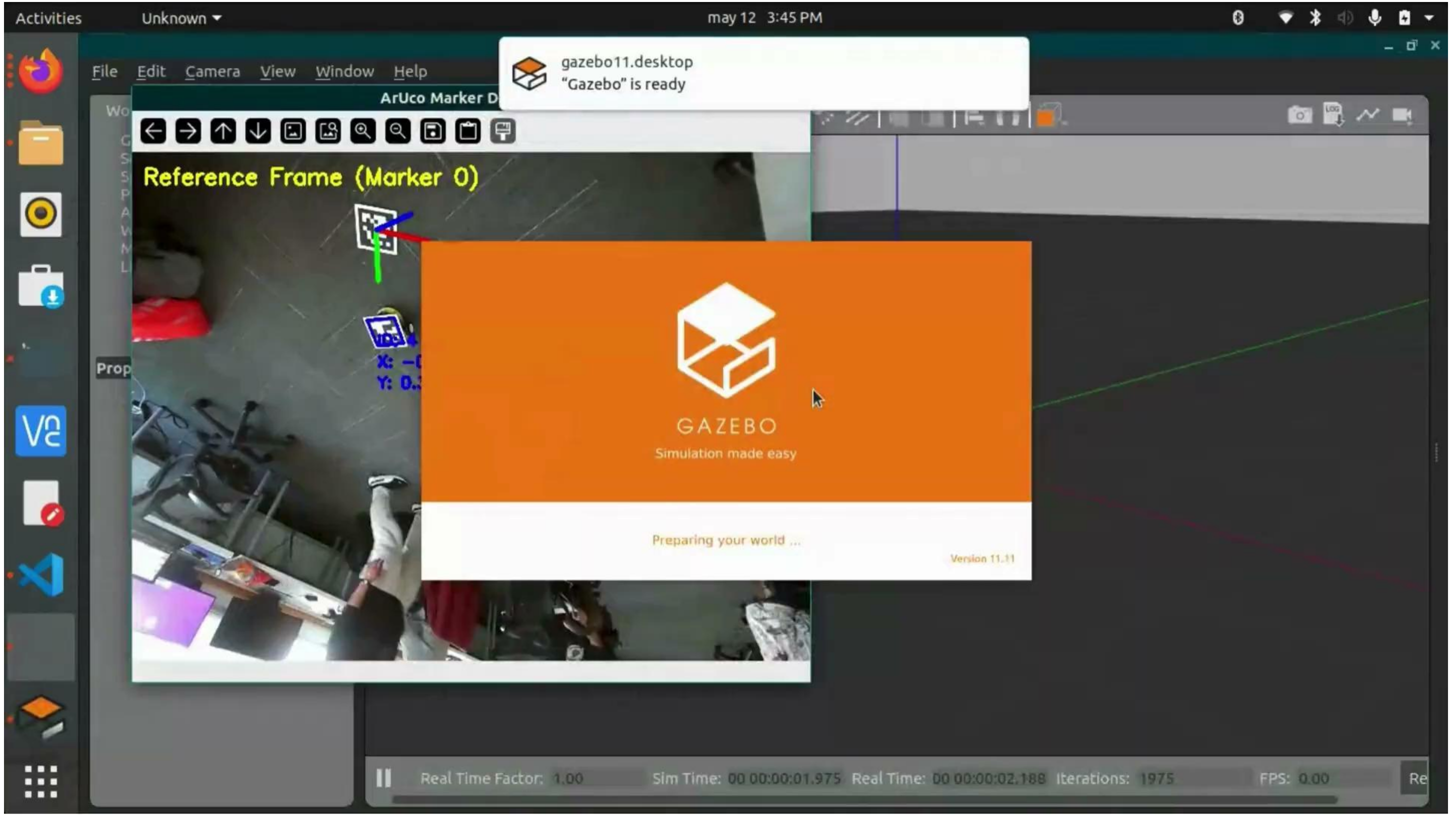
# Video of the system



gazebo11.desktop
“Gazebo” is ready

Reference Frame (Marker 0)

GAZEBO
Simulation made easy

Preparing your world ...

Version 11.11

Real Time Factor: 1.00 Sim Time: 00 00:00:01.975 Real Time: 00 00:00:02.188 Iterations: 1975 FPS: 0.00

# Conclusions

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# Conclusions

- **Implementation Success:**
  - The project operated successfully despite numerous hotfixes.
- **Modularity Challenges:**
  - The ChoiRbot framework's modularity was less than anticipated.(N ≠ 6).
- **Control Strategies:**
  - While complex controllers excel in simulations, simpler, more robust controllers are preferred for real-world applications due to ease of debugging and reliability.
- **Lack of Peer review validation.**

# Question?