SkiROS2

A skill-based Robot Control Platform for ROS

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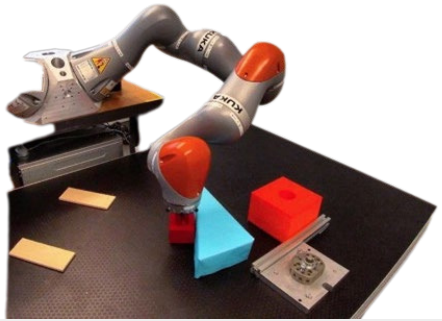
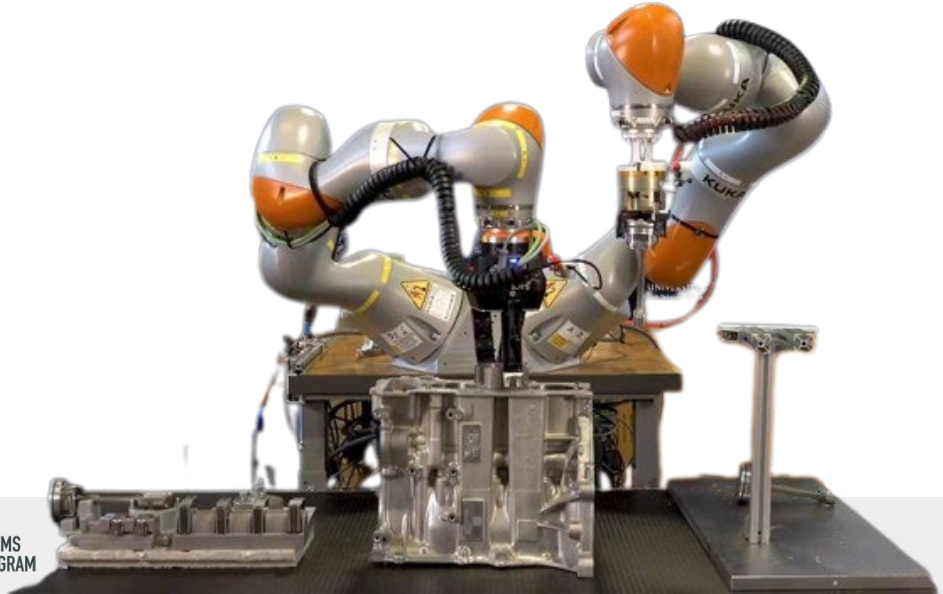
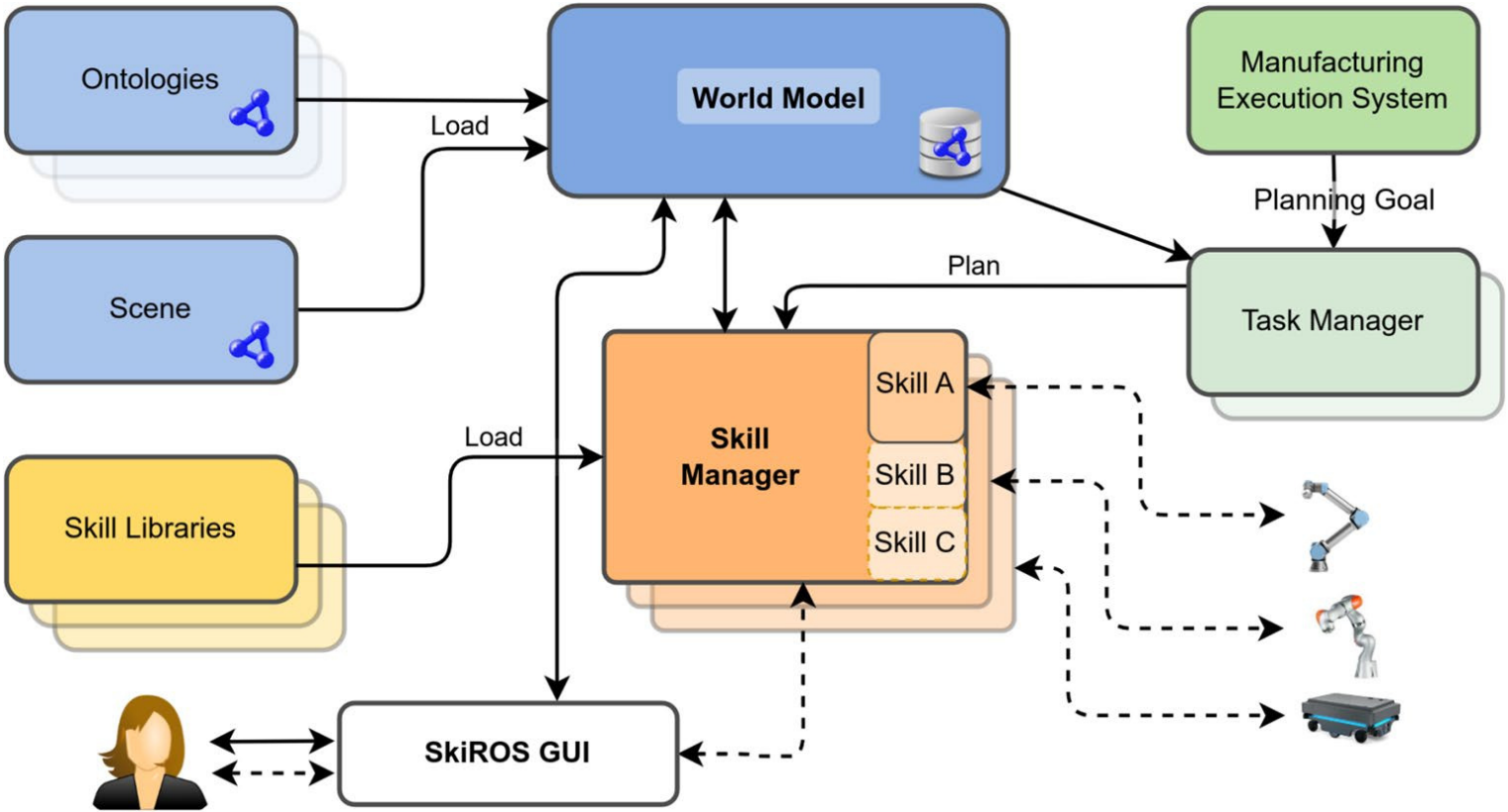




A platform for Intelligent and Autonomous Robots

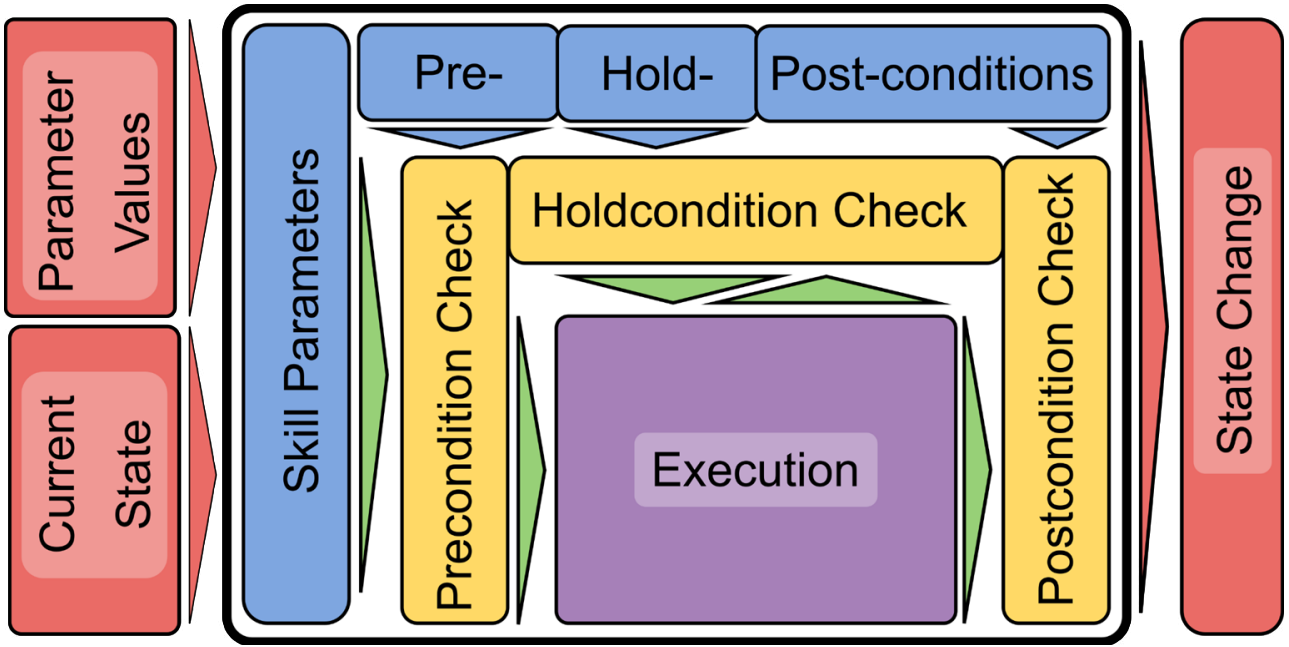


What is a skill?

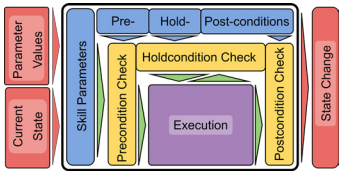
*“Skills [...] are **parametric procedures** that modify the world model (world state), bringing it from an **initial state** to a **final state** according to their **pre- and post-conditions**.”* [1]

[1] https://github.com/RVMI/skiros2/wiki/Overview-3:-Skill-model

Skill Model


Parameter Values
Current State
Skill Parameters
Pre-
Hold-
Post-conditions
Precondition Check
Holdcondition Check
Execution
Postcondition Check
State Change

Skill Model



Skill Description

- Semantic level
- Parameters
- Pre-, hold- and post-conditions

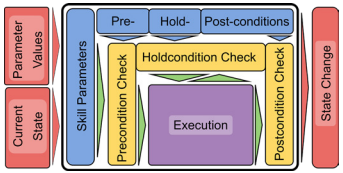
```
class Drive(SkillDescription):
    def createDescription(self):
        # =======Params=========
        self.addParam("Robot", Element("cora:Robot"), ParamTypes.Required)
        self.addParam("TargetLocation", Element("skiros:Location"), ParamTypes.Required)
        self.addParam("Velocity", 0.5, ParamTypes.Optional)
        self.addParam("StartLocation", Element("skiros:Location"), ParamTypes.Inferred)
        # =======PreConditions=========
        self.addPreCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "StartLocation", True))
        # =======PostConditions=========
        self.addPostCondition(self.getRelationCond("NoRobotAt", "skiros:at", "Robot", "StartLocation", False))
        self.addPostCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "TargetLocation", True))
```

Skill Implementation

- Implements one description
- Different implementations of one description
- Can modify the description

```
class drive_fake(SkillBase):
    def createDescription(self):
        self.setDescription(Drive(), self.__class__.__name__)

    def expand(self, skill):
        skill.setProcessor(SerialStar())
        skill(
            self.skill("Wait", "wait", specify={"Duration": 1.0}),
            self.skill("WmSetRelation", "wm_set_relation", remap={'Src': "Robot", 'Dst': "StartLocation", },
                       specify={'Relation': 'skiros:at', 'RelationState': False}),
            self.skill("WmSetRelation", "wm_set_relation", remap={'Src': "Robot", 'Dst': "TargetLocation"},
                       specify={'Relation': 'skiros:at', 'RelationState': True})
        )
```

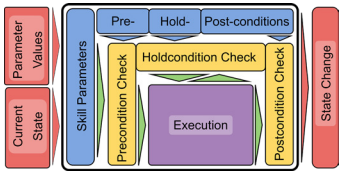
Skill Description



- Parameters
  1. Required
  2. Optional
  3. Inferred
- Conditions
  1. Preconditions
  2. Holdconditions
  3. Postconditions
- Condition Types
  1. Relation Condition
  2. Property Existence
  3. Property Value

```
class Drive(SkillDescription):
    def createDescription(self):
        # =======Params=========
        self.addParam("Robot", Element("cora:Robot"), ParamTypes.Required)
        self.addParam("TargetLocation", Element("skiros:Location"), ParamTypes.Required)
        self.addParam("Velocity", 0.5, ParamTypes.Optional)
        self.addParam("StartLocation", Element("skiros:Location"), ParamTypes.Inferred)
        # =======PreConditions=========
        self.addPreCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "StartLocation", True))
        # =======PostConditions=========
        self.addPostCondition(self.getRelationCond("NoRobotAt", "skiros:at", "Robot", "StartLocation", False))
        self.addPostCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "TargetLocation", True))
```

Skill Implementations: **Primitive Skills**



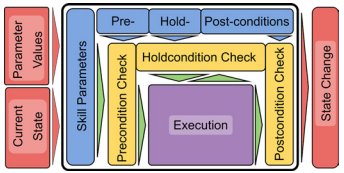
- Semantically atomic actions
- Typically directly interact with an API
- Examples:
  - Gripper actuation
  - Arm manipulation
  - Sensor input

Code Skeleton:

- Implement one skill description
- Python functions for start, execution, …
- Return “running”, “success” and “failure”

```python
class my_primitive(PrimitiveBase):
    def createDescription(self):
        """Set the primitive type"""
        self.setDescription(MyPrimitive())

    def onInit(self):
        """Called once when loading the primitive. If return False, the primitive is not loaded"""
        return True

    def onPreempt(self):
        """ Called when skill is requested to stop. """
        pass

    def onStart(self):
        """Called just before 1st execute"""
        return True

    def onEnd(self):
        """Called just after last execute"""
        pass

    def execute(self):
        """ Main execution function """
        return self.success("Done")
```

Skill Implementations: **Compound Skills**

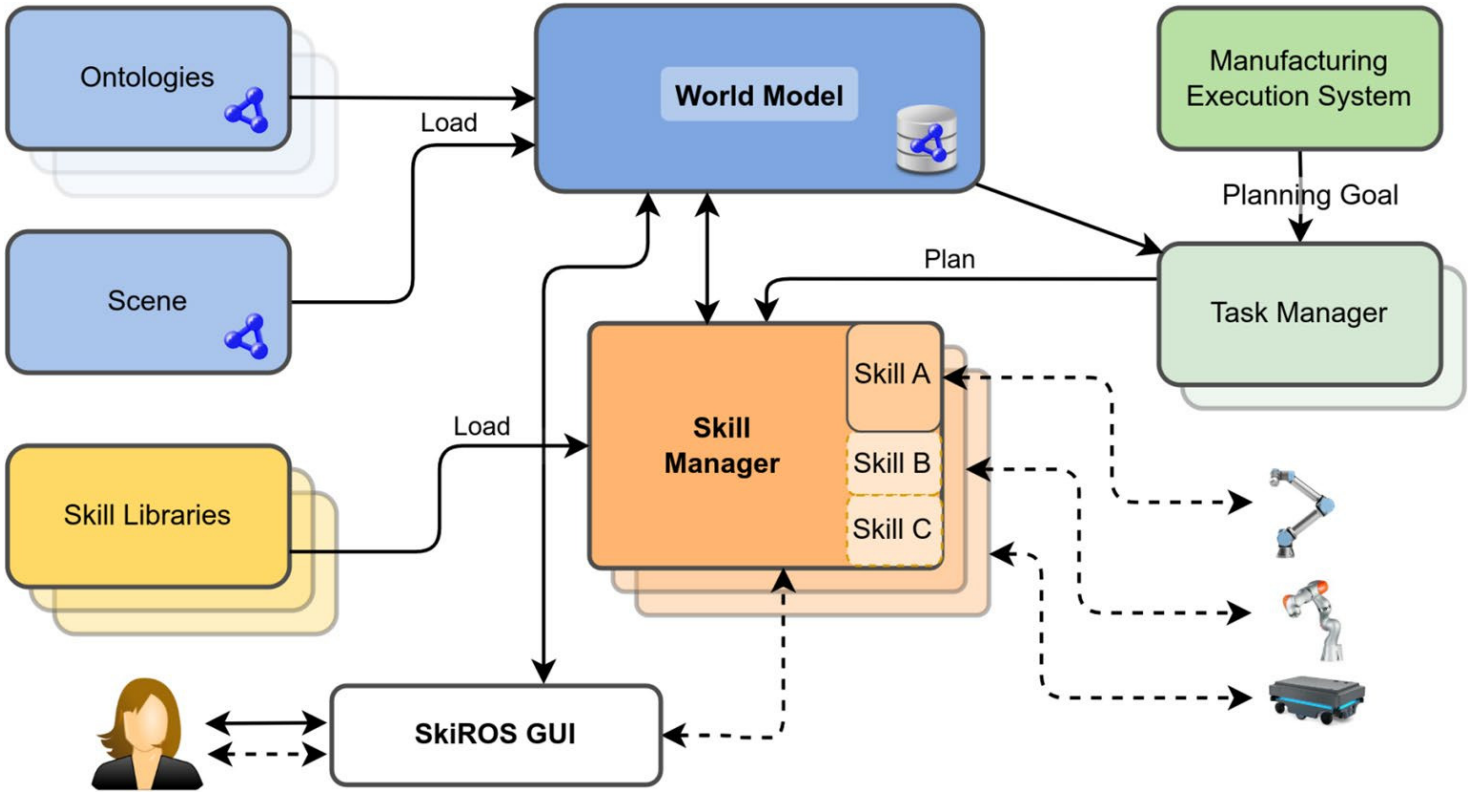


- Combine several compound skills and primitives
- *Extended Behavior trees*
- Processors
  - Serial (AND)
  - Selector (OR)
  - Parallel
  - …
- Automatic selection of implementations

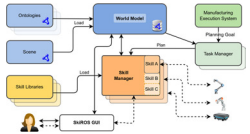
Compound Skill Implementation:

```
class drive_fake(SkillBase):
class drive_platform(SkillBase):
class drive_platform(SkillBase):
class drive_platform(SkillBase):
    def createDescription(self):
        self.setDescription(Drive(), self.__class__.__name__)

    def expand(self, skill):
        skill.setProcessor(SerialStar())
        skill(
            self.skill(SelectorStar())(
                self.skill("MovePlatformDirect", "", specify={"Velocity": self.params["Velocity"].values}),
                self.skill("MovePlatformPlanning", "", specify={"Velocity": self.params["Velocity"].values}),
            ),
            self.skill("VerifyPlatformArrival", ""),
            self.skill("WmSetRelation", "wm_set_relation", remap={'Src': "Robot", 'Dst': "StartLocation", },
                       specify={'Relation': 'skiros:at', 'RelationState': False}),
            self.skill("WmSetRelation", "wm_set_relation", remap={'Src': "Robot", 'Dst': "TargetLocation"},
                       specify={'Relation': 'skiros:at', 'RelationState': True})
        )
```

SkiROS2 Architecture



World Model



- Stores knowledge in an RDF graph
- Ontologies
  - Concepts
  - Properties
  - Relations
- Scene has concrete instances
- Enables reasoning and planning

```python
class Drive(SkillDescription):
    def createDescription(self):
        # =======Params=========
        self.addParam("Robot", Element("cora:Robot"), ParamTypes.Required)
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        self.addParam("Velocity", 0.5, ParamTypes.Optional)
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        # =======PreConditions=========
        self.addPreCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "StartLocation", True))
        # =======PostConditions=========
        self.addPostCondition(self.getRelationCond("NoRobotAt", "skiros:at", "Robot", "StartLocation", False))
        self.addPostCondition(self.getRelationCond("RobotAt", "skiros:at", "Robot", "TargetLocation", True))
```
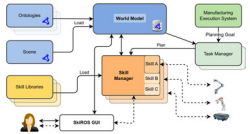
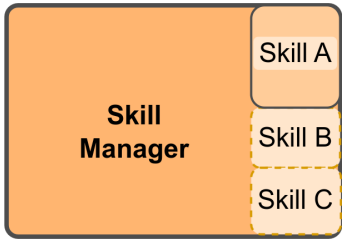
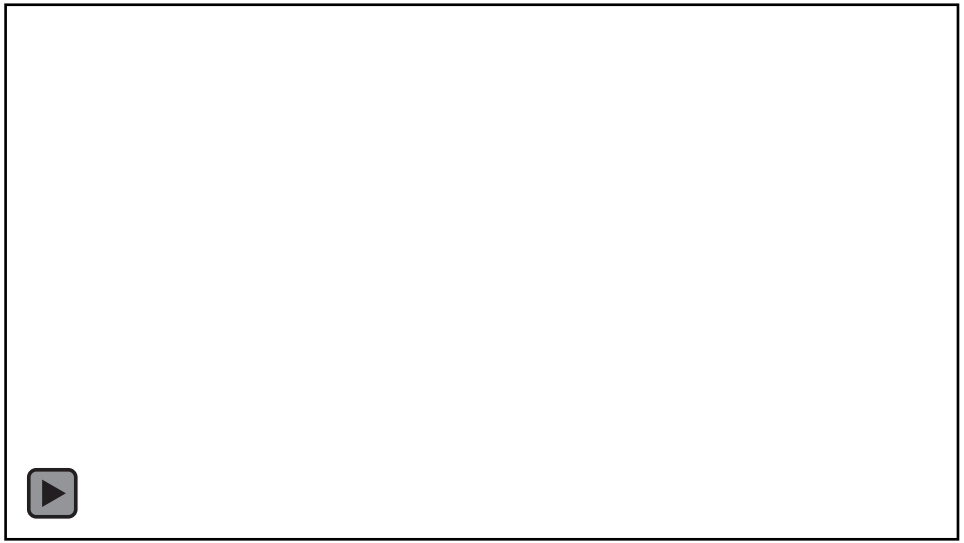

Subject	Predicate	Object
skiros:Container	rdfs:subclassOf	skiros:Location
skiros:DriverAddress	rdfs:subPropertyOf	skiros:DeviceProperty
skiros:Scene-0	skiros:contains	skiros:Location-1
skiros:Robot-2	skiros:at	skiros:Location-1

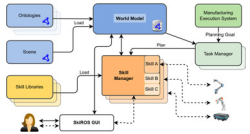


Skill Manager

- Loads skills from skill libraries
- Populates the world model with skill information
- Executes skills
  - Creates a task
  - Skills share a blackboard
  - Grounds skills
  - Automatically selects skills







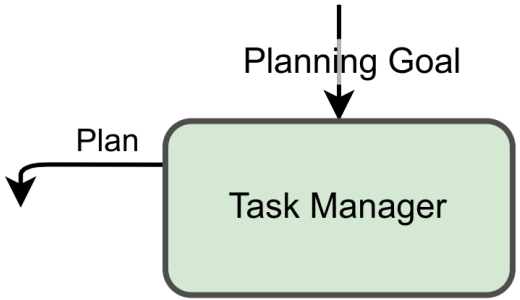
Task Manager for Task-Level Plans

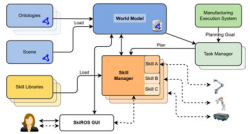
- Receives planning goal such as

  ```
  (skiros:at skiros:Robot-2 skiros:Location-3)
  ```

- Automatically creates a PDDL planning domain
  - Based on the knowledge in the world model

- Uses a PDDL planner (tfd)
- Execution in the skill manager





Integration and GUI

- Turn *ROS Actions* into skills
- GUI
  - Start, tick & stop skills
  - Debug skill execution
  - View and modify the world model
- Python API
  - World model access
  - Skill manager
- *tf*-frames and *RViz* integration
  - Couple frames to world model entities
  - Publish *tf* frames

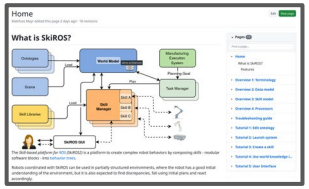
Example Use Cases

SkiROS2 - Summary

- Flexible robot control platform
- Targeted for semi-structured environments
- Knowledge integration and reasoning
- Automatic task-level planning
- Behavior trees
- Reinforcement learning
- ROS 2 support

What will you do with it?

Documentation:



https://github.com/RVMI/SkiROS2/wiki

{Code}:

https://github.com/RVMI/SkiROS2

Paper:

SkiROS2: A skill-based robot control platform for ROS
https://arxiv.org/abs/2306.17030