Tape library automation

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Summary

- General idea
- Functional Requirements
- Tools
- Model and joints
- Scene
- Finite State Machine

General Idea

A tape library is a type of computer storage device that provides high-capacity data storage and retrieval using magnetic tape cartridges. It is designed to efficiently store and manage a large number of tape cartridges in an automated manner.
Two main components:

- **Tape drives:** responsible for reading from and writing to the magnetic tape cartridges
- **Robotic mechanisms:** typically robotic arms, are used to handle and transport the tape cartridges within the library


STORAGETEK

The robotic arms enable the library to perform various automated tasks, but we will focus on:

- Loading and unloading tape cartridges
- Moving the cartridges
- Presenting them to the tape drives for data access

Functional Requirements

- The robotic arm must be able to reach any slot in the library
- The robotic arm must be able to take any cartridge from their slots
- The robotic arm must be able to move any cartridge from its slot to the drive and vice-versa
- The robotic arm must be able to load and unload the cartridge to and from the drive

Tools

- CoppeliaSim Edu, Version 4.5.1 (rev. 5)
- Lua programming language (version 5.2)
- Autodesk Revit 2023

Model and joints

The robot is a cartesian manipulator equipped with a series of three mutually orthogonal prismatic joints.
Starting from the manipulator base, the joints are configured as follows:

1. **X joint:** to align the gripper to the cartridge slot
2. **Z joint:** to align the gripper to the shelf
3. **Y joint:** to perform the grip

Model and joints

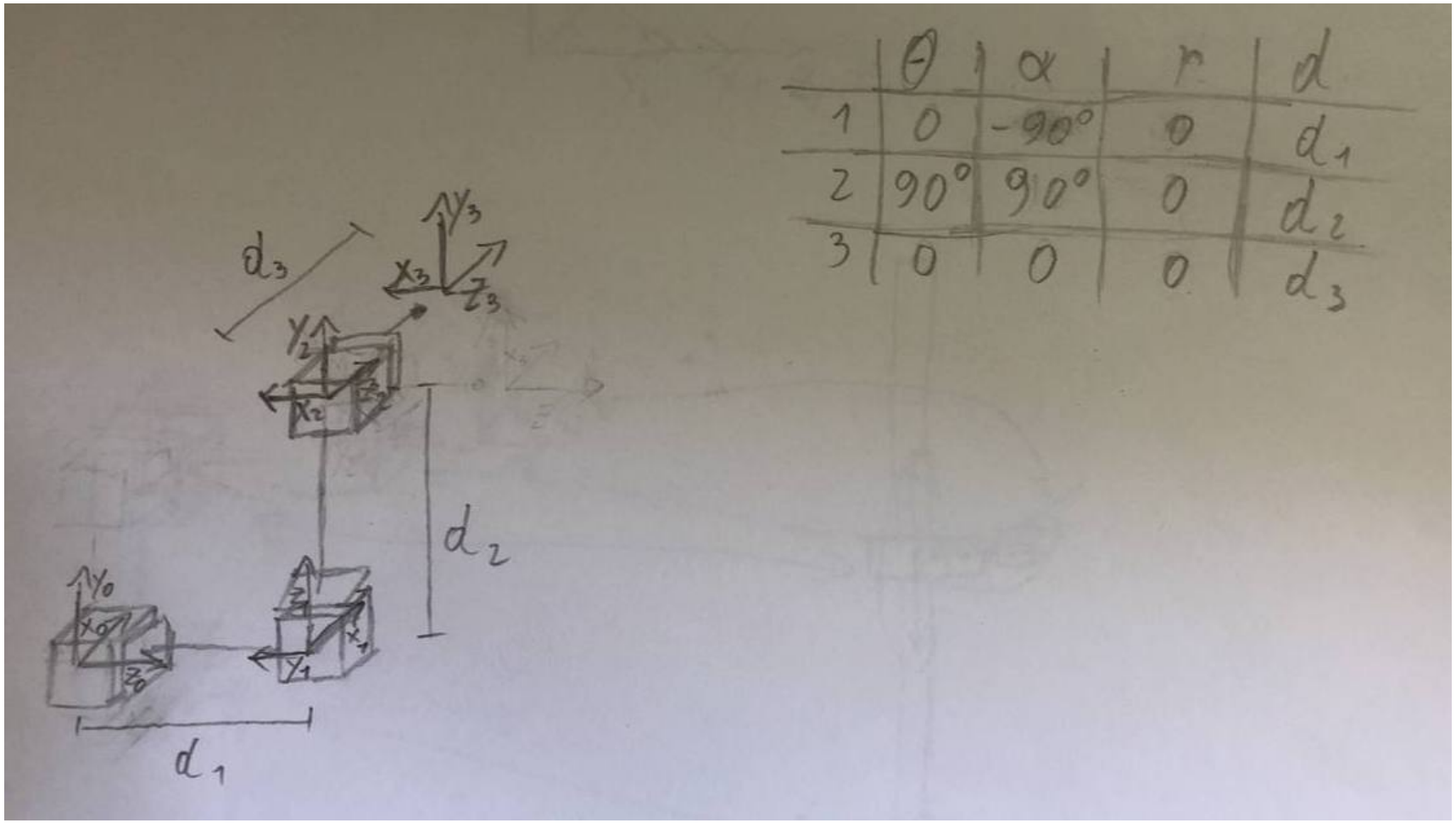


Figure: DH model and table

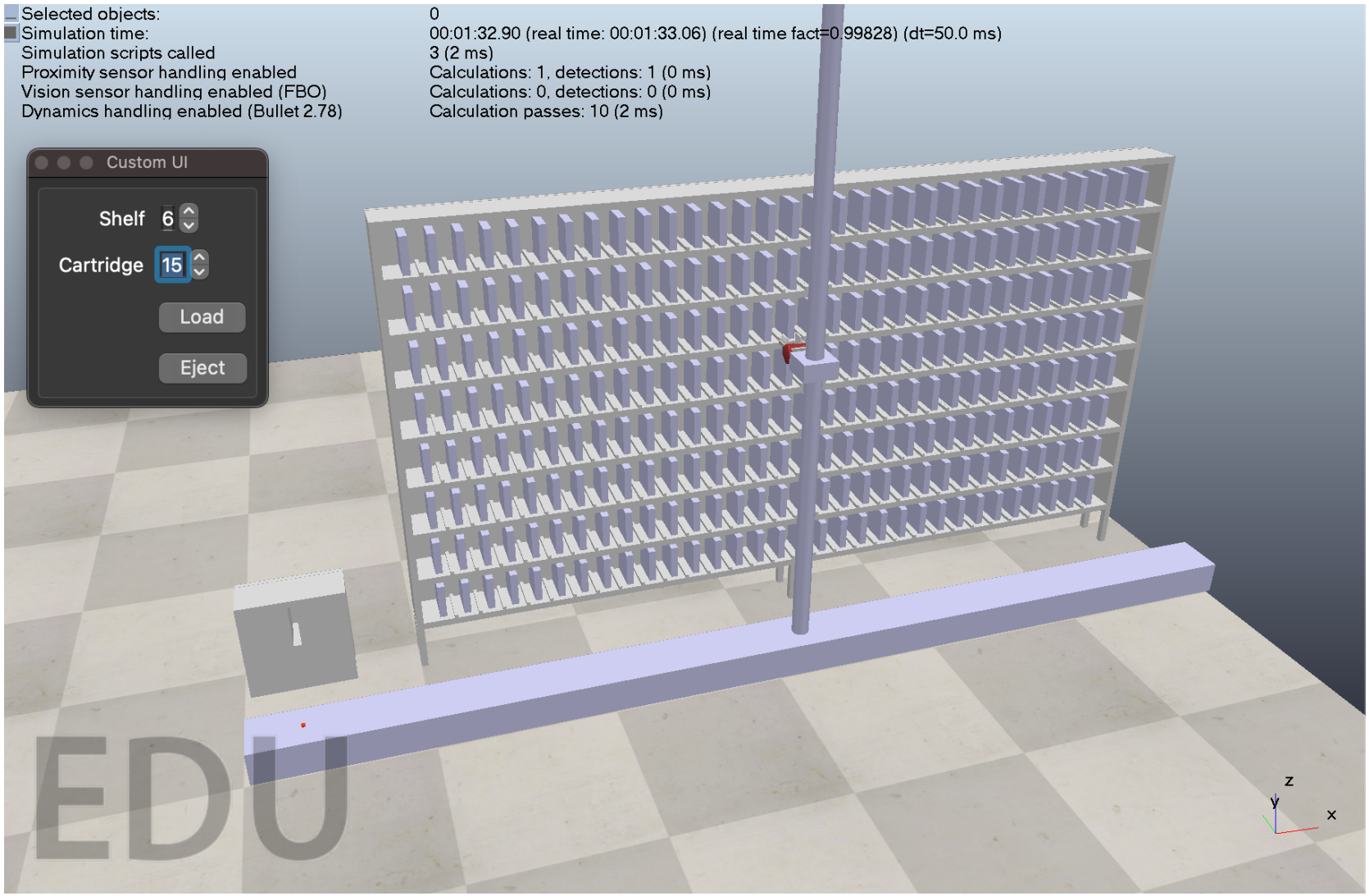
The workspace is a cuboid with the following size:

- X = 2.64 m
- Z = 1.05 m
- Y = 0.15 m

Model and joints

- The adopted end effector is the Baxter gripper, available in the CoppeliaSim model library.
- The end effector is equipped with a laser sensor detecting the presence of the object that has to be picked up.
- The cartridge model has been designed directly using CoppeliaSim.
- The tape drive and the tape rack have been designed using Autodesk Revit.

Scene


Selected objects: 0
Simulation time: 00:01:32.90 (real time: 00:01:33.06) (real time fact=0.99828) (dt=50.0 ms)
Simulation scripts called 3 (2 ms)
Proximity sensor handling enabled Calculations: 1, detections: 1 (0 ms)
Vision sensor handling enabled (FBO) Calculations: 0, detections: 0 (0 ms)
Dynamics handling enabled (Bullet 2.78) Calculation passes: 10 (2 ms)
Custom UI
Shelf 6
Cartridge 15
Load
Eject
EDU
z
y
x

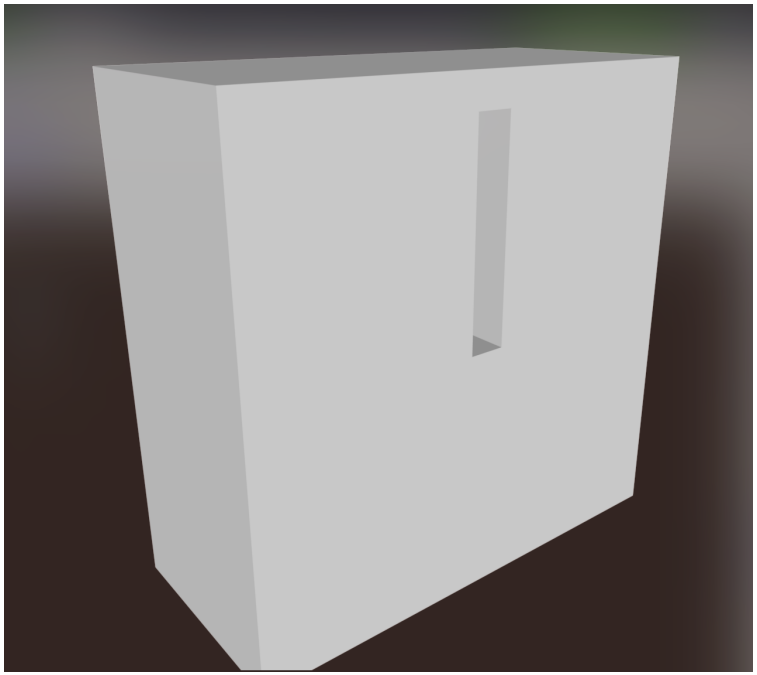


Figure: Drive 3d model (13.5 cm $\times$ 30 cm $\times$ 30 cm)

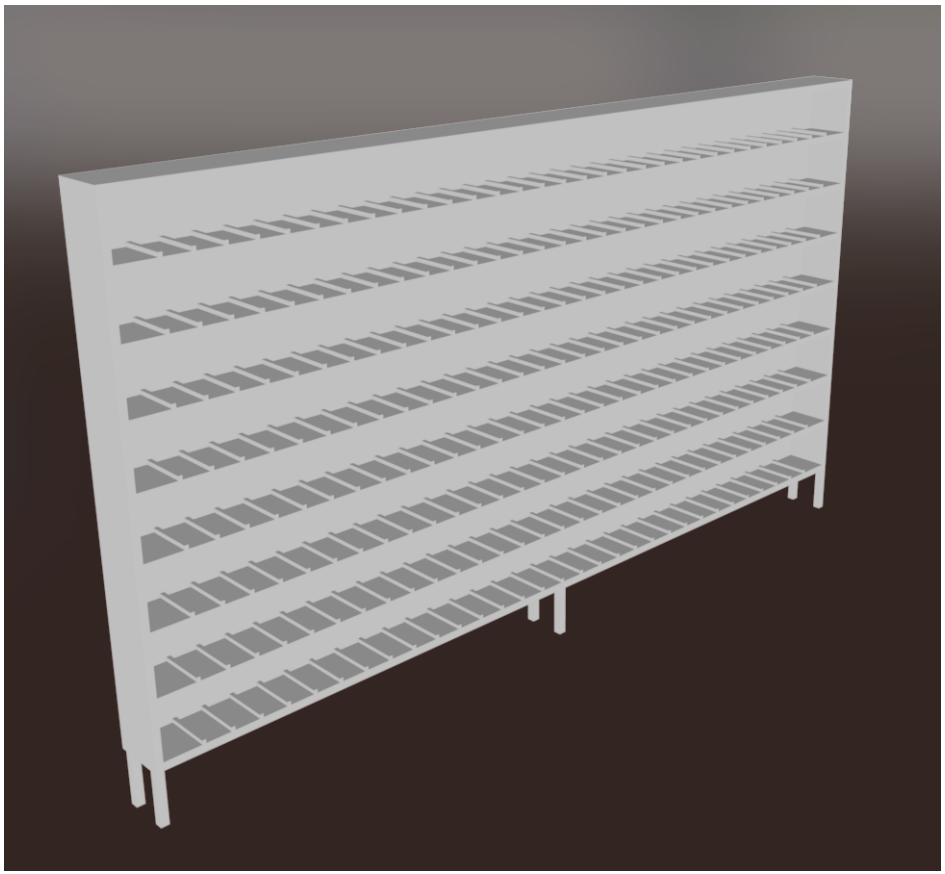


Figure: Rack 3d model (2.38 m $\times$ 0.135 m $\times$ 1.35 m)

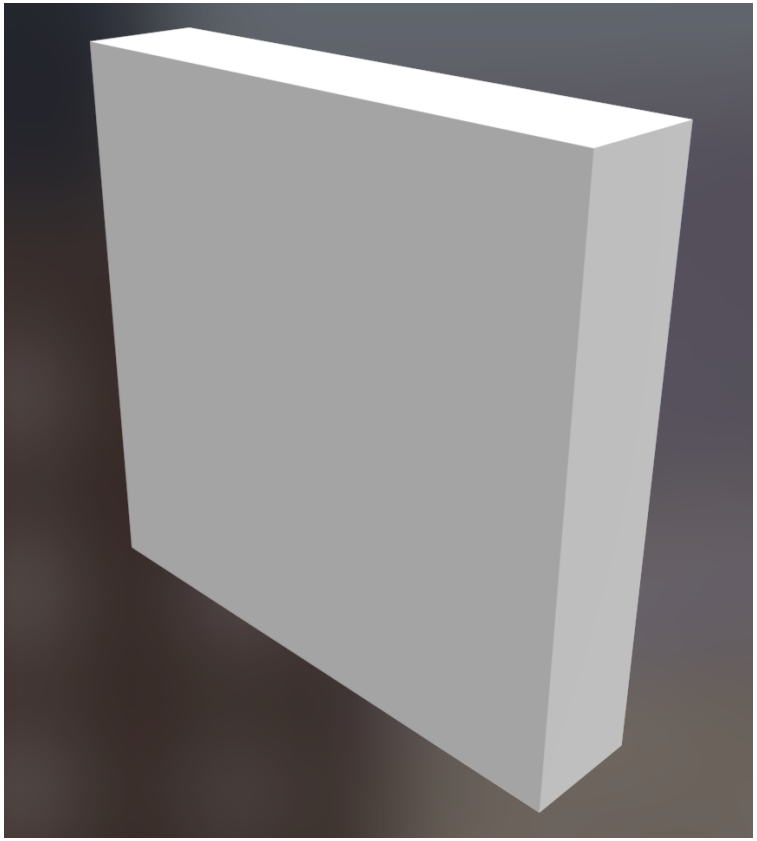


Figure: Cartridge 3d model (102.0 mm $\times$ 105.4 mm $\times$ 21.5 mm)

Figure: Manipulator robot

Scene

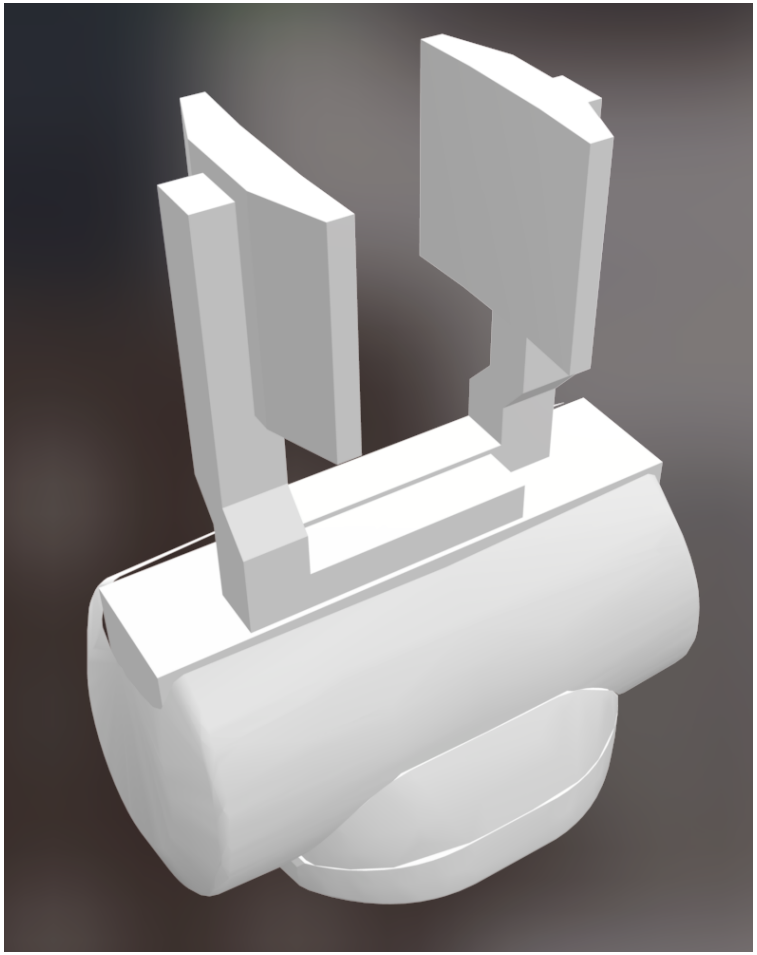
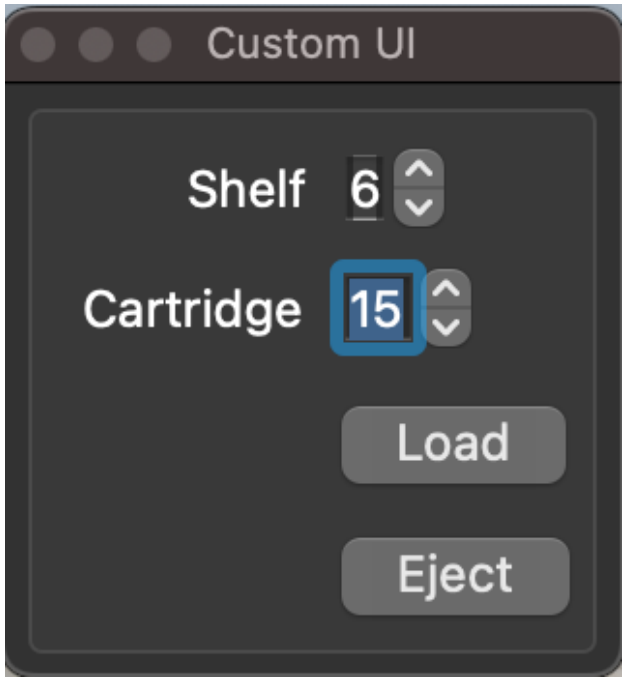
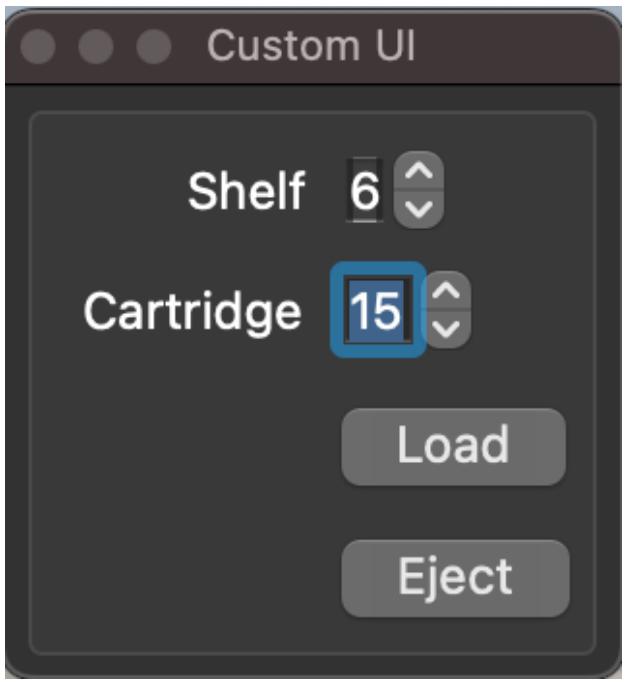


Figure: Baxter gripper

- The robot is entirely controlled by a custom user interface.
- The user can select the slot and the shelf of the cartridge to be loaded.
- The user can eject the currently loaded cartridge, which will be placed at its original slot.



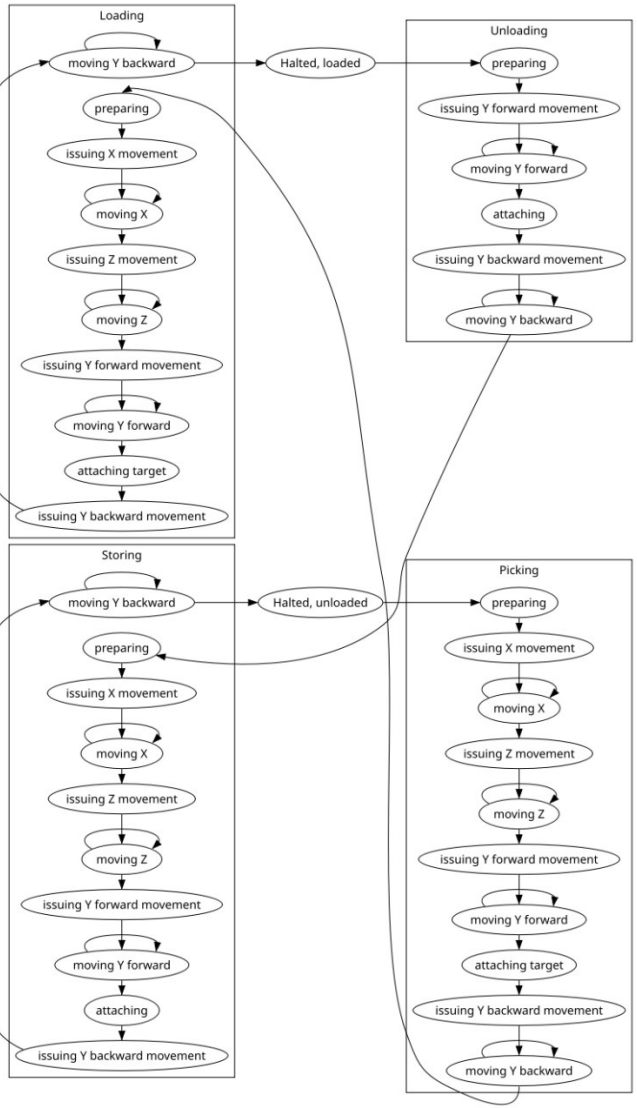
- If a tape is already loaded into the drive, the user can't load another tape.
- If a job is already in progress, the user can't request another operation.
- If a cartridge is not available at the required location, the operation is aborted.



Finite State Machine

- The robot control algorithm is driven by a finite state machine.
- The FSM is organized in four macro blocks, reflecting the four main tasks the robot has to carry out.

Finite State Machine



- **Picking**
  - This sequence of actions is performed when the user asks for a cartridge to be loaded into the tape drive.
  - The robot moves from its current position and aligns its end effector to the required cartridge, picking it from the shelf.
- **Loading**
  - This sequence of actions is performed after the picking stage.
  - The robot aligns its end effector to the tape drive, loading the required cartridge.

- **Unloading**
  - This sequence of actions is performed when the user asks for the currently loaded cartridge in the tape drive to be ejected.
  - The robot, whose end effector is already aligned to the tape drive, takes the cartridge from the drive.
- **Storing**
  - This sequence of actions is performed after the unloading stage.
  - The end effector is aligned to the correct slot of the rack and the robot places the cartridge at its original location.

$$position(shelf, slot) = \begin{bmatrix} base_x + slot \times delta_x \\ offset_y \\ base_z + shelf \times delta_z \end{bmatrix}$$

$$base_x = 0.42\,m$$
$$delta_x = distance + width$$
$$base_z = 0\,m$$
$$delta_z = 0.15\,m$$
$$distance = 0.05\,m$$
$$width = 0.02155\,m$$

References


A Complete CoppeliaSim Tutorial (V-REP), Leopoldo Armesto (Universitat Politècnica de València)


Coppelia user manual