# Kinova Gen3 Robotic Arm Simulation & Gripper Design

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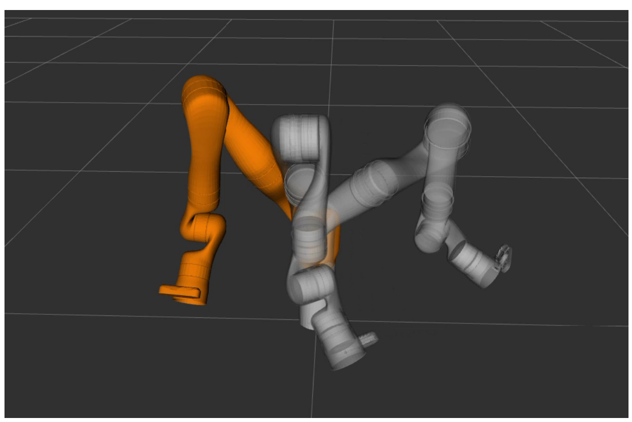
## Project Overview

This project involved developing a ROS 2-based simulation and control system for a Kinova Gen3 6-DOF robotic arm, alongside designing a custom gripper for surgical tools. The arm was modeled in a Gazebo simulation with MoveIt for motion planning, and `rclpy` (ROS 2 Python) scripts were created to perform point-to-point inverse kinematics (IK) motions. A 3D-printed two-finger gripper was engineered in SolidWorks to grasp 6–8 mm diameter surgical instruments using high-friction contact and was verified via stress analysis. The integrated system enabled interactive grasp control and demonstrated stable manipulation of the surgical tool in both simulation and real-world tests.

## Simulation and Inverse Kinematics



Simulated motion trajectory of the Kinova Gen3 arm moving between two defined poses in the Gazebo environment. The development began by building a realistic simulation of the Kinova Gen3 robotic arm using ROS 2, MoveIt, and Gazebo. The 6-DOF arm's kinematic model was implemented with accurate link lengths and joint limits as per the manufacturer's specifications, providing a reach of approximately 90 cm.

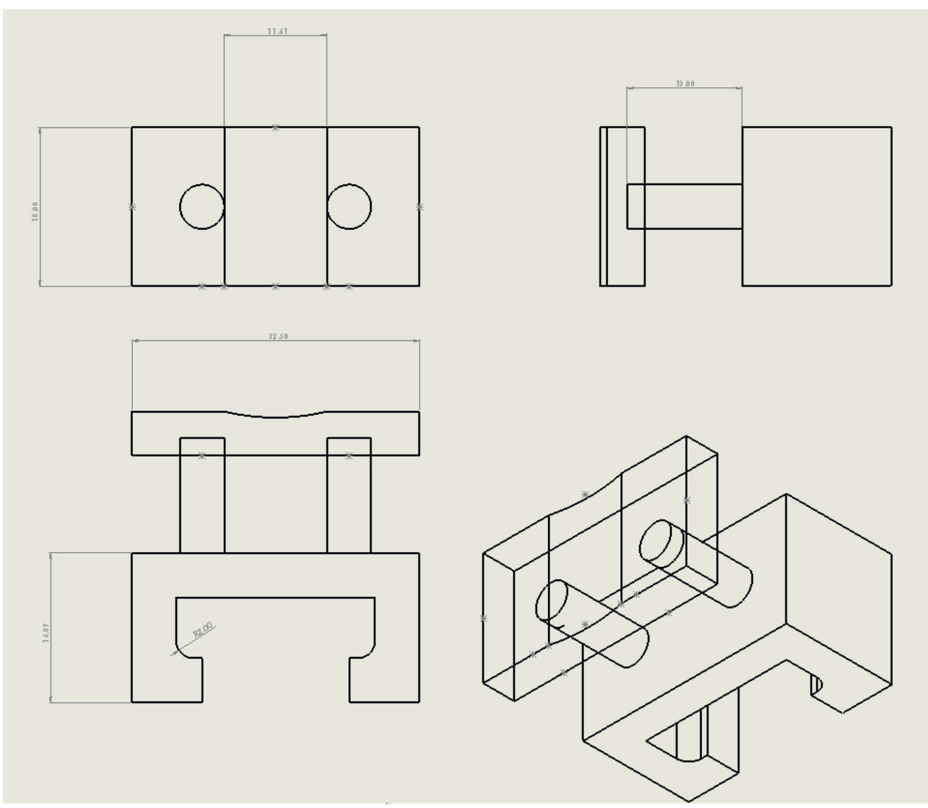
Using MoveIt's inverse kinematics solver through custom `rclpy` scripts, the robot could compute joint configurations for target end-effector poses and execute smooth point-to-point trajectories. This allowed the arm to reliably reach specified waypoints with precision. The IK motion planning was validated in Gazebo to ensure the arm's movements were collision-free and within joint bounds.

## Link Dimensions (approximate):

- Base to shoulder joint (Actuator 2): 284.8 mm
- Upper arm link 1 (Actuator 2 $\rightarrow$ 3): 210.4 mm
- Upper arm link 2 (Actuator 3 $\rightarrow$ 4): 210.4 mm
- Forearm link (Actuator 4 $\rightarrow$ 5): 208.4 mm
- Wrist link (Actuator 5 $\rightarrow$ 6): 105.9 mm
- End-effector adapter (Actuator 6 to tool): 61.5 mm

These link lengths define the robot's kinematic structure used in the IK calculations. The arm's Denavit–Hartenberg parameters and joint coordinate frames were set up in the URDF model, allowing the IK solver to accurately compute solutions. The ROS 2 + MoveIt framework was used to plan trajectories and execute reliable motion paths.

## Gripper Design and Analysis




SolidWorks CAD drawing of the custom gripper jaws with key dimensions (in mm). The gripper was designed to securely hold 6–8 mm diameter instruments using friction.

A custom two-finger gripper was designed to attach to the Kinova arm for surgical instrument manipulation. The design features concave jaw surfaces and slots sized to cradle cylindrical instruments. High-friction contact pads (e.g., rubber or TPU) were used to ensure the tool was held securely through friction without requiring a rigid clamp.

A finite element analysis (FEA) was conducted using SolidWorks Simulation to ensure structural integrity under clamping forces. The analysis verified that maximum stress remained below material yield strength. Fillet reinforcements and geometry adjustments were added based on stress distribution.

## Testing & Results

Physical test: The Kinova Gen3 arm equipped with the custom 3D-printed gripper, holding a surgical instrument securely by friction.

After simulation validation, the gripper was mounted on the real Kinova Gen3 arm. Using an interactive ROS 2 control interface, the arm was commanded to grasp and manipulate the instrument. The gripper's high-friction contact ensured stable grasping, even during arm motion.

The system successfully demonstrated accurate IK-based point-to-point movement and stable physical manipulation, indicating its potential for assisting in surgical applications.

## Skills Used

- **Robot Simulation:** ROS 2, MoveIt, and Gazebo environment setup for 6-DOF arm
- **Motion Planning & IK:** Python (`rclpy`) scripting for trajectory generation
- **CAD & Mechanical Design:** SolidWorks modeling of surgical gripper
- **Finite Element Analysis:** Stress analysis to evaluate structural performance
- **Prototyping:** 3D printing and physical integration with Kinova Gen3
- **Robotics Integration:** ROS 2 interface for grasp control and hardware testing