Towards a Biomimetic and Dexterous Robot Avatar: Design, Control, and Kinematics Considerations

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Vertically Integrated Projects Program

NSF

Introduction

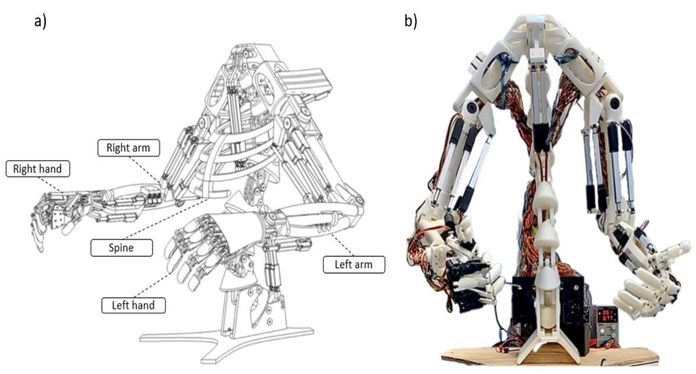
The Athena Upper Body Robot

- Athena is a lightweight, 3D printed humanoid robot, built by undergraduates participating in the Vertically Integrated Projects (VIP) program at Georgia Tech [1].
- We aim for low-cost robot design while achieving high-fidelity motion control performance.
- Athena serves as a platform to explore both dexterous grasping of various objects and trajectory generation for agile manipulation tasks.

Long-Term Goal:

- Integrate Athena with Cassie, a bipedal robot acquired from Agility Robotics [2] and hosted in the LIDAR lab, to aim for unified locomotion and manipulation.

Design



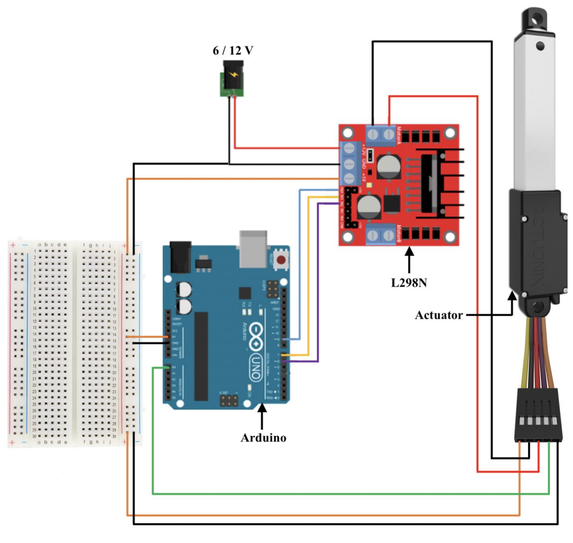
Objective: Design a lightweight humanoid upper body robot to achieve dexterous motion and manipulation.

Design originated from Youbionic [3]:

- Subsystems:
  - Spine
  - Two Arms
  - Two Hands

- Athena's Composition
  - Total Mass: 11 kg
  - Total Degrees of Freedom: 28
  - 40 Actuonix Linear Actuators
    - Designed to mimic human muscles

Components 3D Printed using ABS for lightweight design.

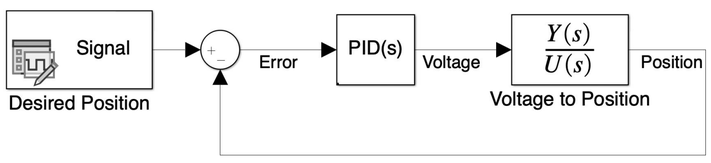


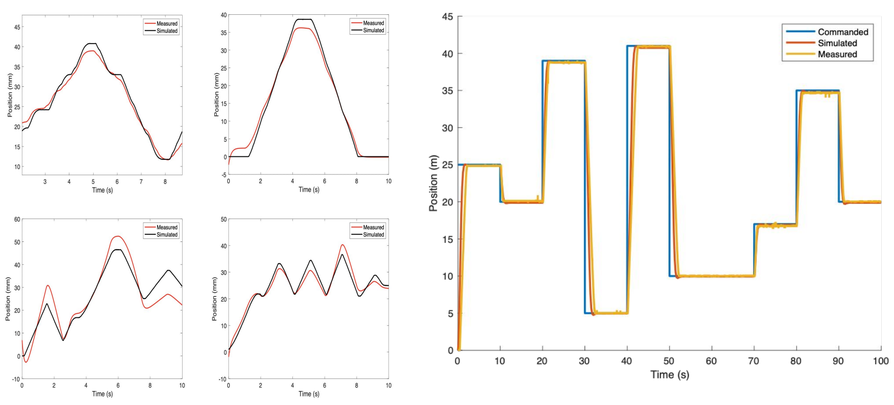
Control

Objective: Achieve accurate joint-level position control to execute agile manipulation tasks.

- Used System ID to characterize voltage-position relationship.
- Designed PID controllers for position control of each actuator.
- Compared predicted and actual controller performance.

The Athena Control team is planning to explore learning-based or optimal control methods.



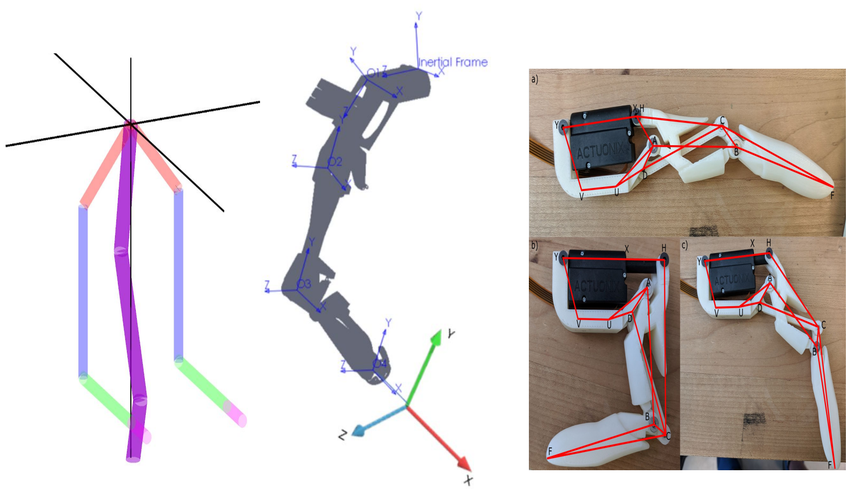


Kinematics

Objective: Develop methods to convert between joint angles and cartesian position in the workspace.

- Wrote arm kinematic functions using homogeneous transformation matrices and the Newton-Raphson root finding algorithm.
- Wrote hand kinematic functions using four-bar trigonometric relationships.

The Kinematics team is investigating novel path planning and optimization algorithms for decision making in Athena's workspace.



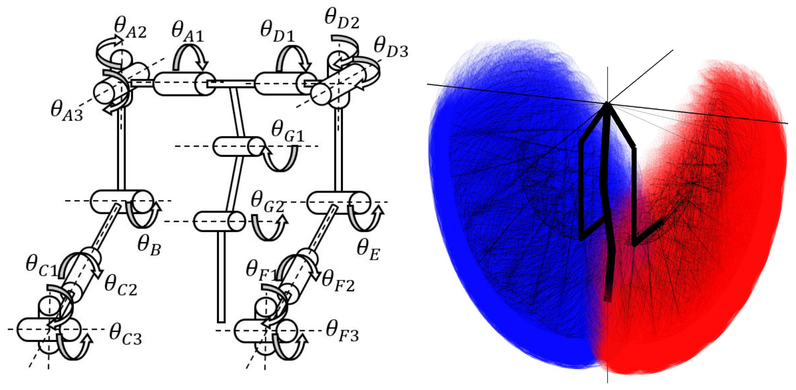
Conclusion and Discussion

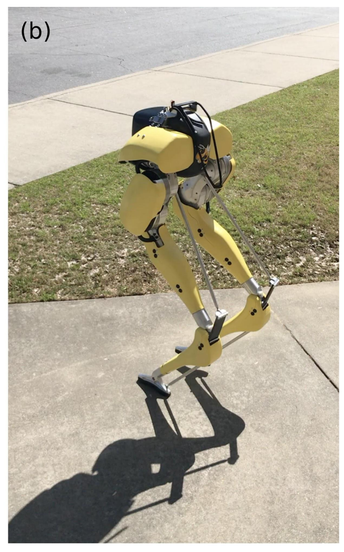
Athena serves as a proof of concept for a biomimetic and dexterous robot avatar with a high degree of accessibility due to its lightweight and low-cost design.

- 3D printed components are combined with linear actuators to form the robot's limbs and muscles.
- Controllers are designed using a transfer function relating each actuator's input voltage to its position.
- Desired position and orientation are converted to joint angles using an inverse kinematics root-finding algorithm.

Future Work:

- Optimize the mechanical design to allow for improved accuracy and motion fluidity.
- Study learning-based or optimal control methods.
- Integrate a newly built Athena head robot with cameras and target vision-based grasping.





References

[1] Vertically Integrated Projects, "http://www.vip.gatech.edu/."
[2] Agility Robotics, "http://www.agilityrobotics.com/."
[3] Youbionic, "http://www.youbionic.com/."

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