VIRGINIA TECH

Grounded Force Feedback Arm with Haptic Glove

Team

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Team Introduction

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1. Introduction - Problem Statement

- Customer: Dr. Leonessa, director of the TREC Lab
- Objective: Apply forces on a user's hand while in VR
- Applications: Video games and training simulations

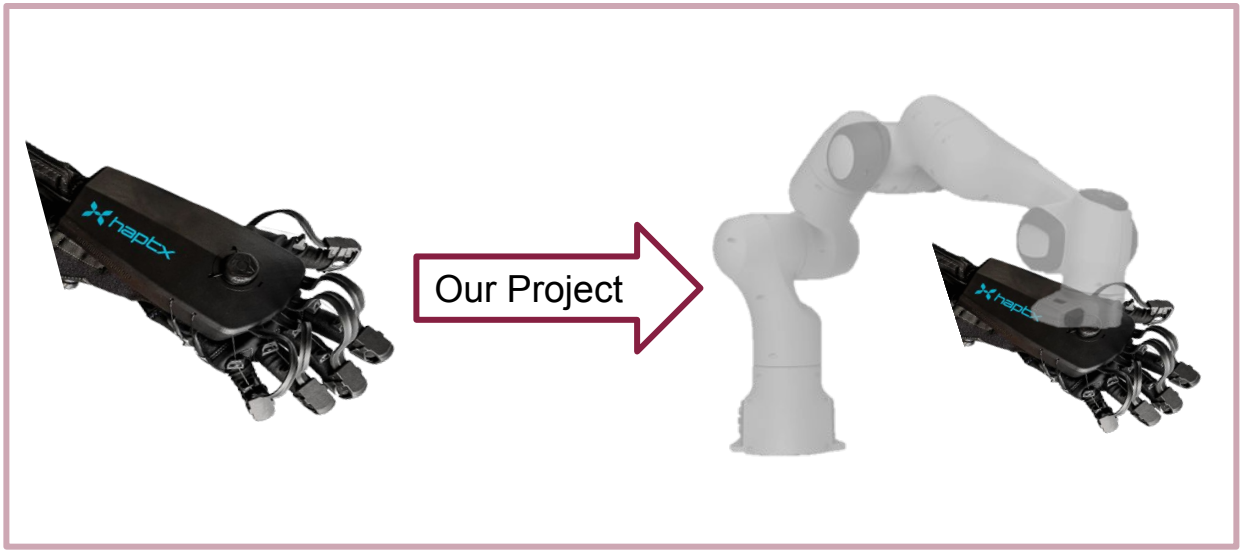
Video Games

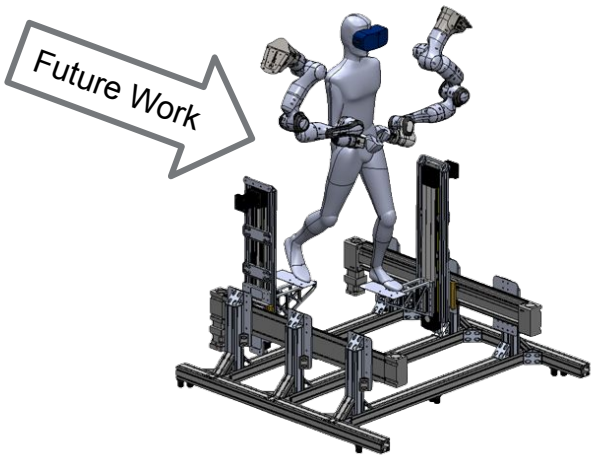
Safety Training

Metaverse

1. Introduction - Requirements

- HaptX gloves for user to interact with virtual world
- Robotic arm to apply forces on hand
- Future integration with TREC Lab's ForceBot





1. Introduction - Engineering Characteristics

Engineering Characteristics		
Customer needs	**Customer Need Description**	**Weighting (1-5)**
1	Safety	5
2	Transparency	5
3	Stay Within Budget	4
4	Compatibility with ForceBot	4
5	Accurate Simulation Dynamics	4
6	Range of Motion of the Arms	4
7	Low Power Consumption	3
8	System Physical Comfort	2
9	Visual Appeal of System	1

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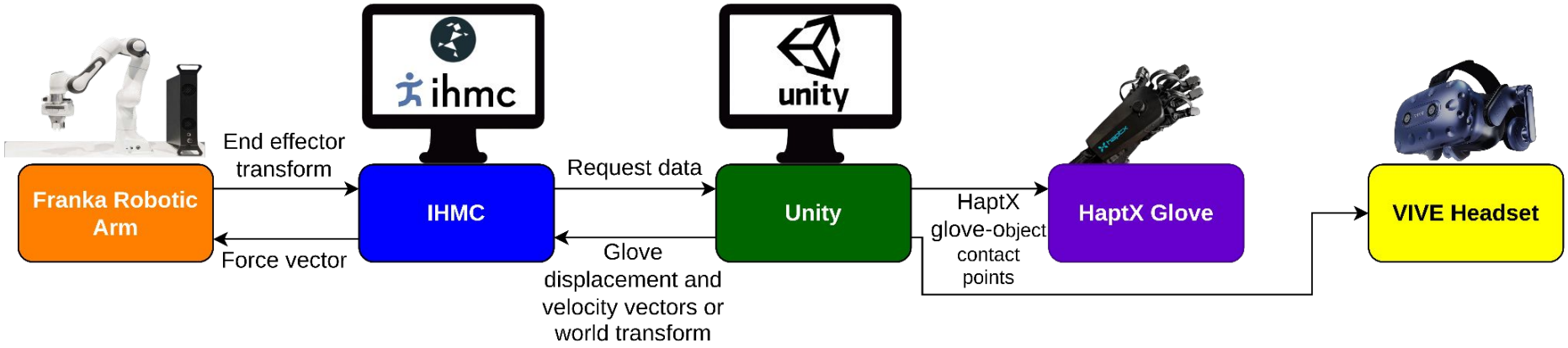
2. Architecture Design



Communication Pipeline

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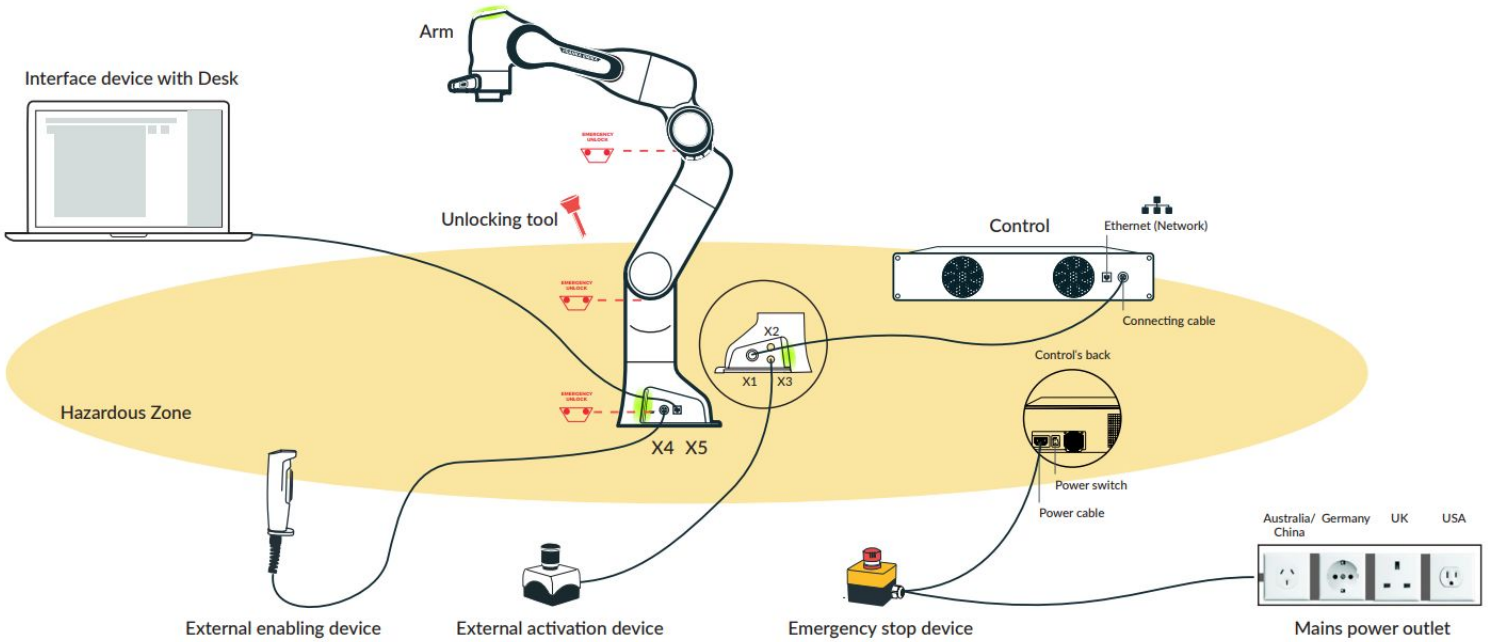
3. Hardware - Franka Robotic Arm

	Panda Arm	KR810	KR1205	DOBOT CR103m
Price ($)	**27,000**	28,900	32,111	56,500
Max Payload (kg)	3	**10**	5	5
Reach (mm)	855	850	1200	**1525**
Self-weight (kg)	**18**	23.5	23	74
Force Sensing	**All Axes**	No torque of force sensing	Six axis force/torque sensor on end effector	N/A
Degree of Freedom	**7**	7	7	6
Max Speed (m/s)	2	**3**	**3**	**3**
Max Acceleration (m/s^2)	**8**	**8**	**8**	**8**
Software Interface	**C++ Libfranka, ROS**	**C++ Extension, ROS**	**C++ Extension, ROS**	Lua

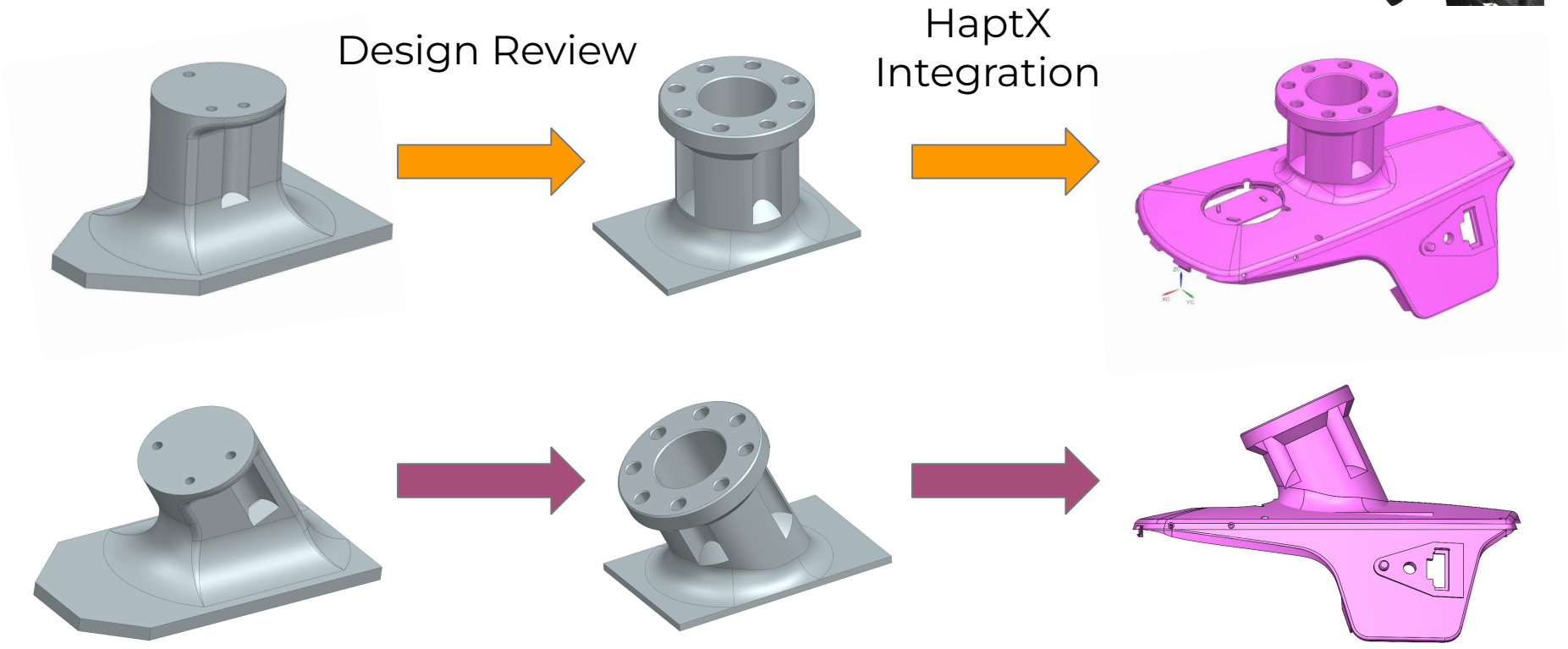
3. Hardware - Franka Robotic Arm



	Panda Arm
Max Payload (kg)	3
Reach (mm)	855
Force Sensing	All Axes
Degree of Freedom	7
Max Acceleration (m/s^2)	8

3. Hardware - Mount Design

- Worked with HaptX to develop new 3D printed glove backplates



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3. Hardware - Other Components

- HaptX Glove

- VIVE Headset

- Base Stations

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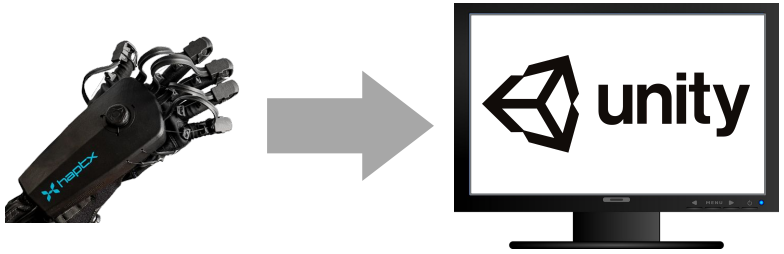
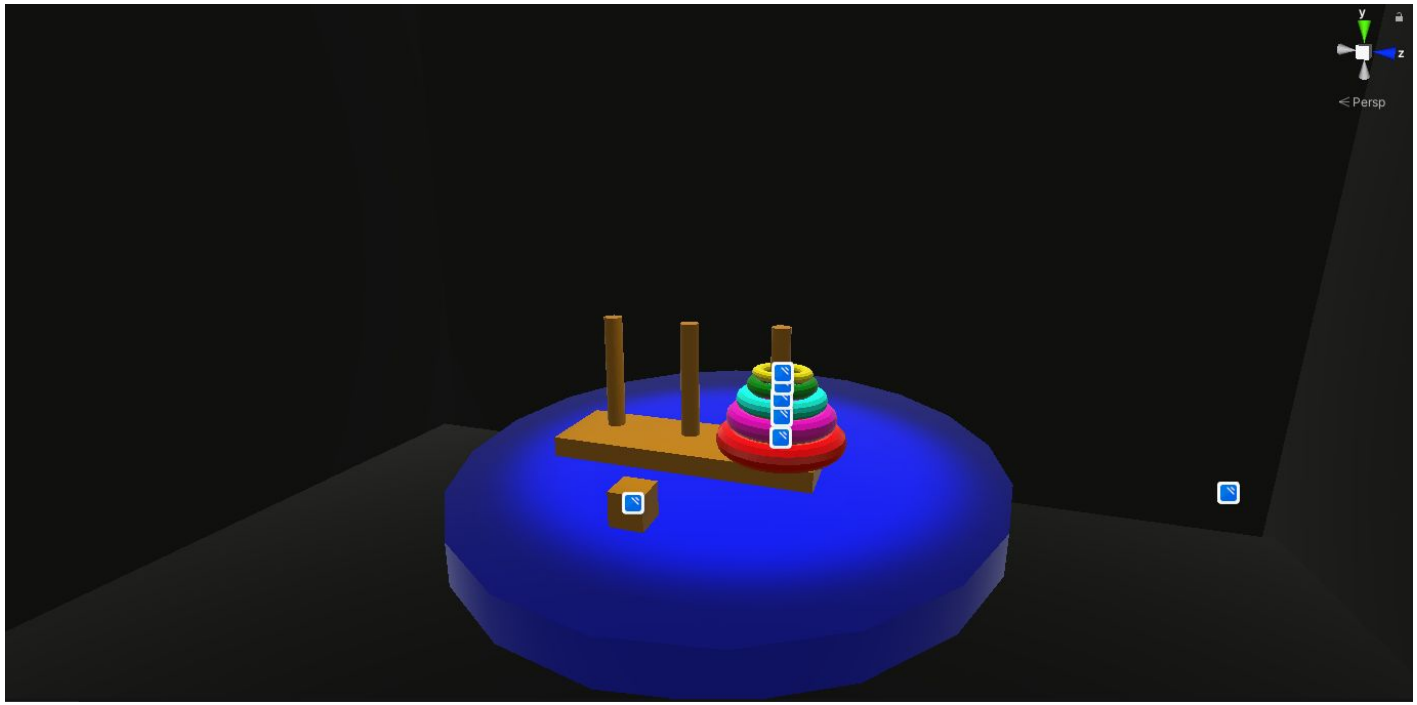
4. Software - Unity

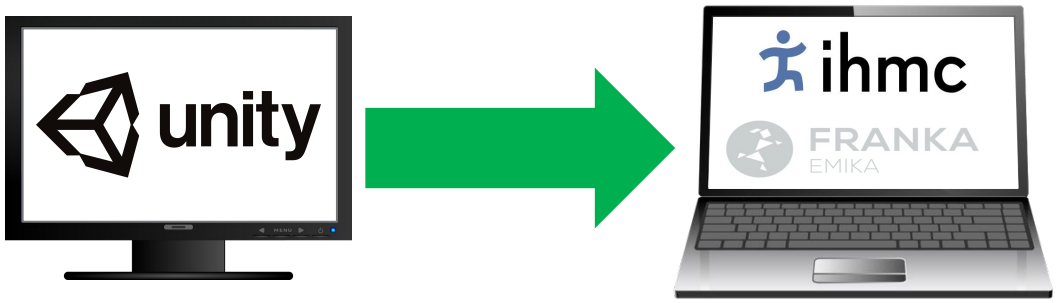
- Interact with environment through VR scenarios
- Extract information from interactions in environment





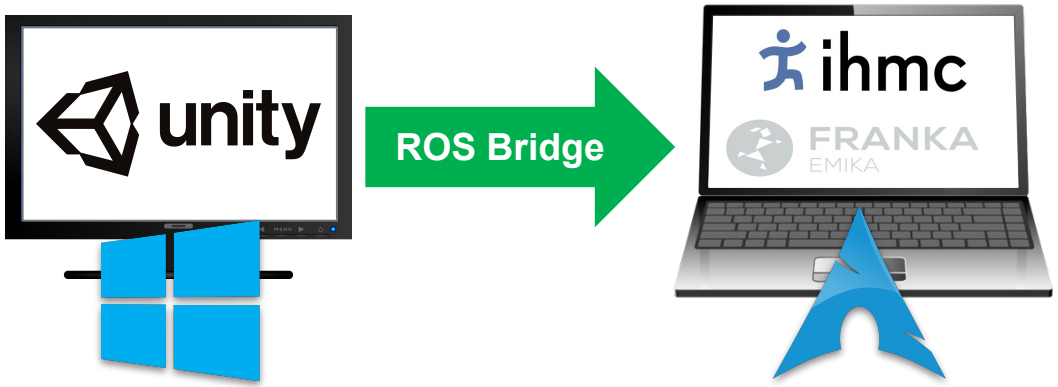
4. Software - IHMC

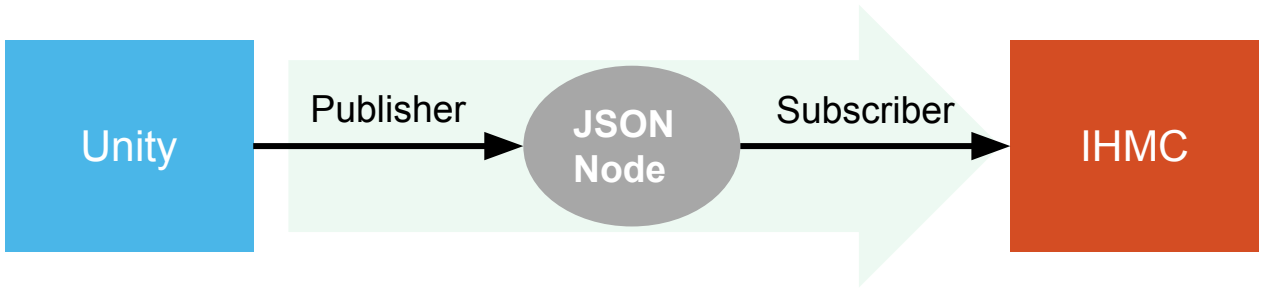
- Open source software
- Necessary for integration with ForceBot
- Mediator between Unity and arm



4. Software - ROS Bridge

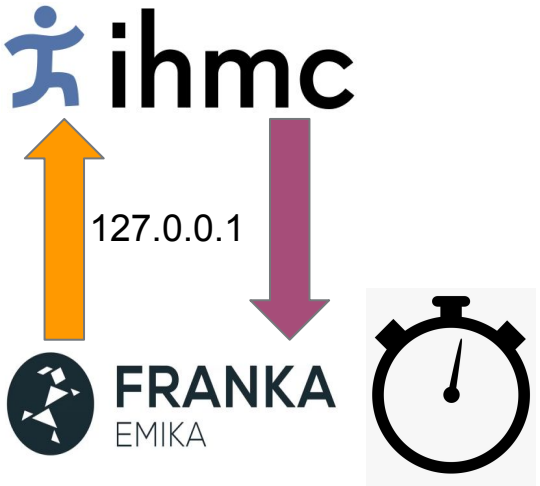
- Unity and IHMC are on separate platforms
- ROS Bridge connects Unity with IHMC
- Configured bridge to send information used to recreate forces





4. Software - Real-time Kernel

- Real-time kernel on Arch Linux
- Local host TCP socket connects IHMC and Libfranka
- Meticulously calculated socket connection timing



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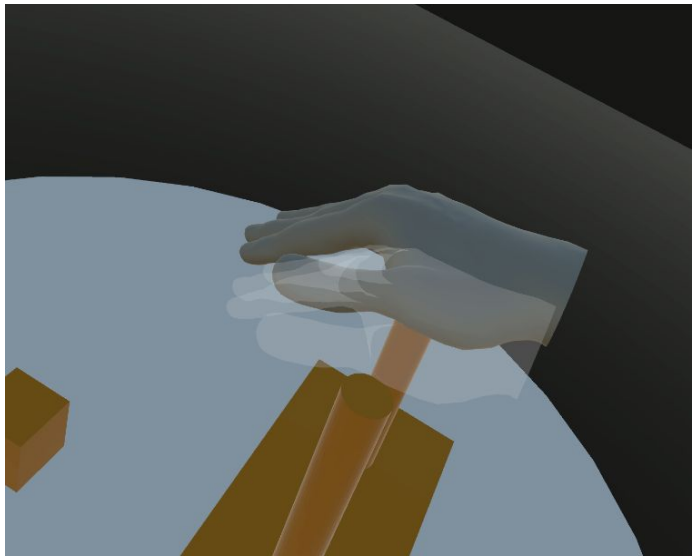
5. Challenges - Force Extraction

- Initial attempts used only object mass
- Current implementation uses displacement and velocity of hand
- Two hand poses in Unity: virtual hand and ghost hand
- Extract displacement between poses and velocity of hand

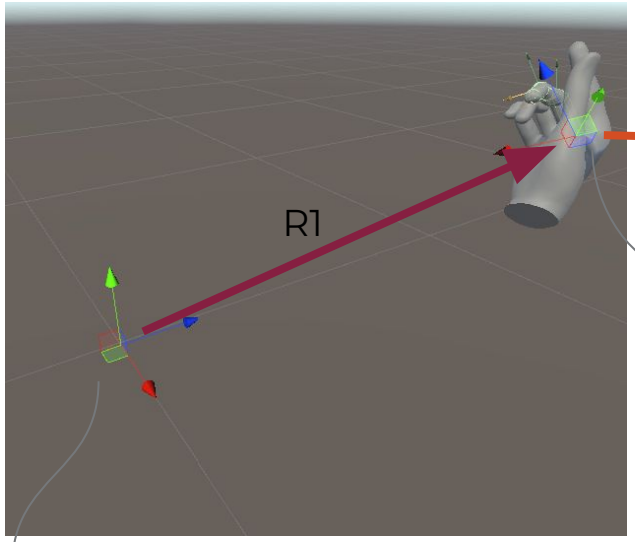


5. Challenges - Axis Alignment

- Unity world frame unaware of arm frame
- Transform displacement and velocity vectors from virtual environment to real world

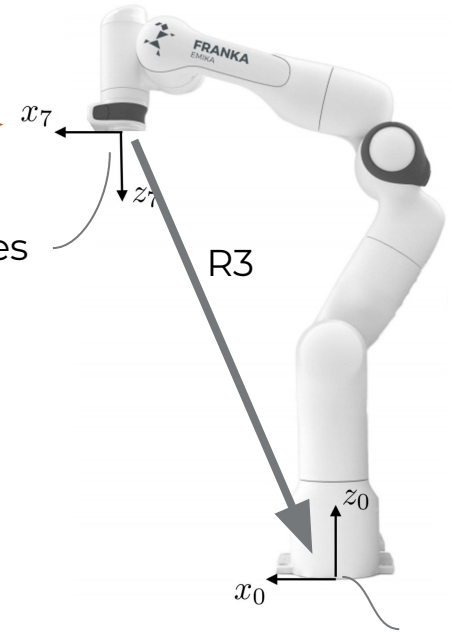
Left-handed frame

Right-handed frame



Change of basis and R2

Local glove frames

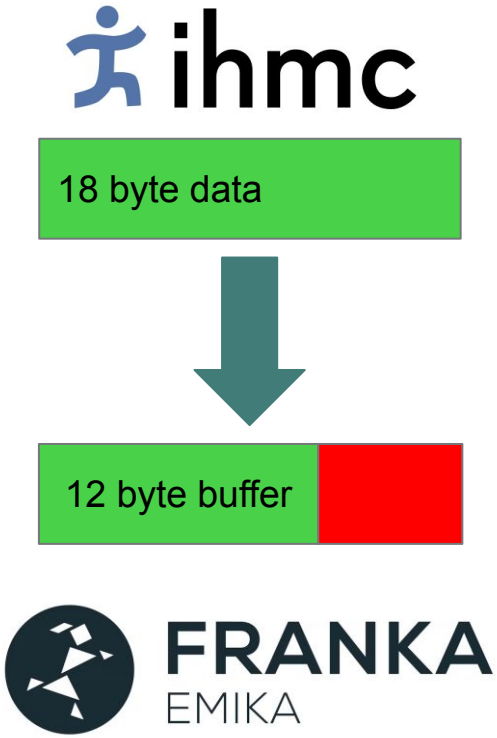


Unity global reference frame

Arm global reference frame

5. Challenges - IHMC to Frankalib Delay

- There was a delay between IHMC and the Panda arm
- Java socket library sent values as a string larger than buffer
- Resulted in a data backlog and a loss of transparency



5. Challenges - IHMC to Frankalib Integrity

- Newline characters signified end of data frame
- IHMC inserts random newline characters into data frame
- Use semicolon to signify end of data frame
- Newline characters ignored in data stream

ihmc

FRANKA EMIKA

X	1000

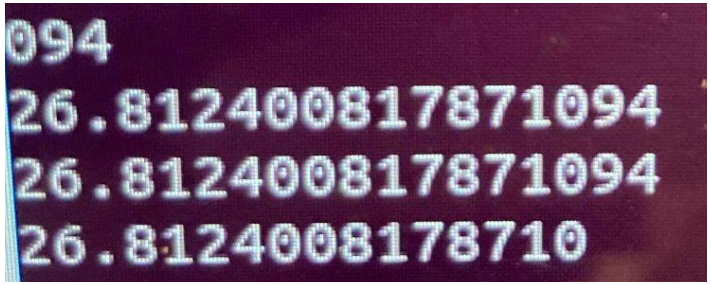
10\n00\n

X	10

X	1000

10\n00;\n

X	1000



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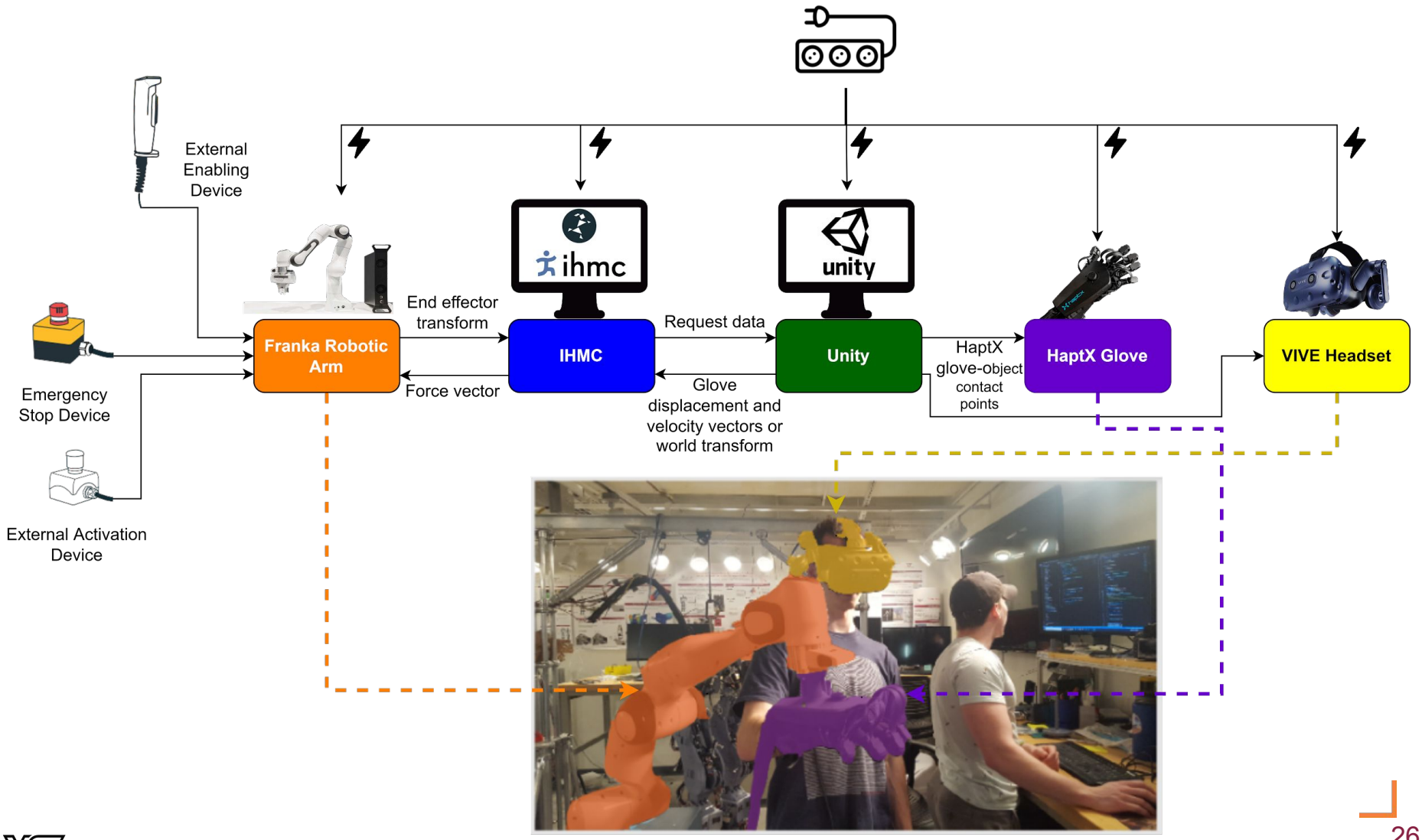
6. End-to-end Communication Pipeline



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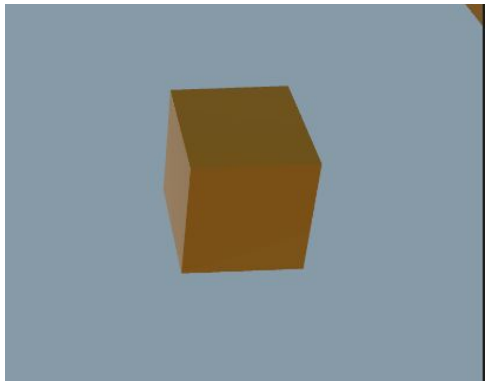
7. Testing

Objects:

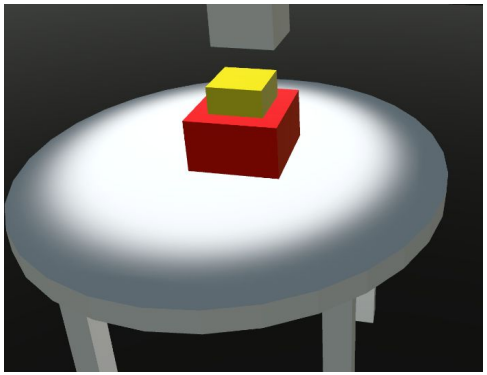
- Cube
- Table
- Tower of Hanoi

Implementations:

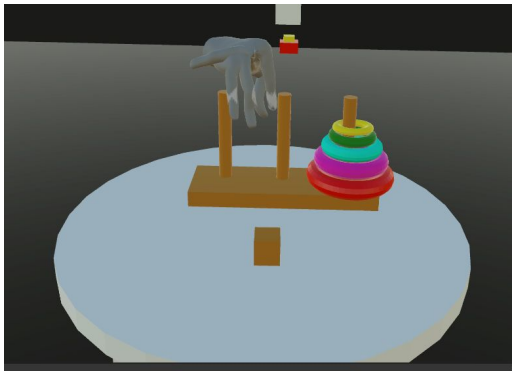
- Use object mass only
- Separate processes for static and dynamic objects
- Generalized forces using glove displacement



Cube



Table



Tower of Hanoi

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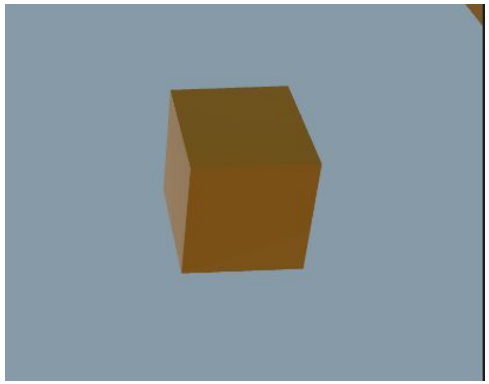
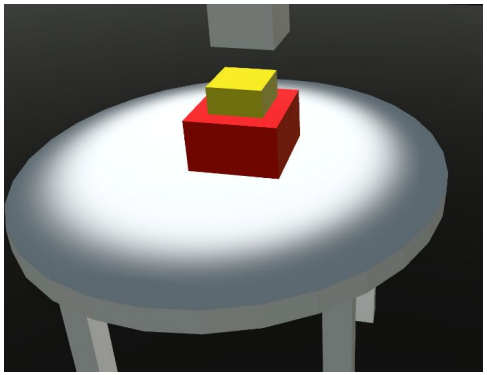
8. Results & Analysis

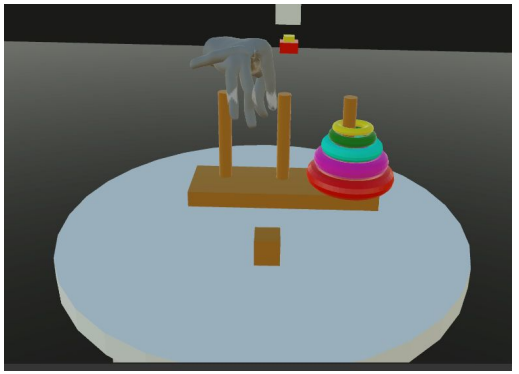
Implementations	Cube (1-10)	Table (1-10)	Tower of Hanoi (1-10)
Use Object Mass Only	5	1	1
Separate Processes for Static and Dynamic Objects	5	4	5
Generalize Forces Using Glove Displacement	6	8	7



Cube



Table



Tower of Hanoi

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8. Future Work

- Integration with lower half of ForceBot

Acknowledgements

- Dr. Alexander Leonessa for the use of the TREC Lab and his dedication to the team's success

- Jesper Smith for his contribution of ROS Bridge functionality to IHMC Open Robotics Software

- Dr. Du and his students Qi Zhu and Tianyu Zhou for sharing research on Unity force extraction

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Thank you!

Q&A