Inverse Kinematics and Full-body Tracking for Virtual Reality

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1 ELEVATOR PITCH

My goal is to experiment with full body tracking in virtual reality in order to better understand that can contribute to a user's sense of presence in VR experiences. I will start by implementing inverse kinematics algorithms that can work using only the headset and controllers as tracking points and animate a torso and arms in VR to try and correspond with the posing of the player's actual body. After this, I will try to improve the arm tracking further by using additional tracking points on the arms. If this goes smoothly, I will aim to extend the IK model to include the legs and feet using additional tracking points. My stretch goal is to be able to implement a small pose matching game as a final deliverable that allows for the various IK algorithms that I implement to be actively used and compared.

2 EXTENDED OVERVIEW

[Lang 2016] http://root-motion.com/2016/06/inverse-kinematics-in-dead-and-buried

This article talks about VRIK, a IK solver designed for VR games and included in a plugin called FinalIK. This is a really good example of what I want to aim for in this project in terms of being able to animate a full character using tracked points in VR, but I hope to be able to expand on this by adding additional tracked points using the VIVE trackers. Although the article doesn't show any of the math being done explicitly, it gives helpful details about different design consideration and challenges in creating a full body IK solver that works using only the controllers and headsets. Specifically, it breaks down the process of producing a full body pose into steps that I will certainly want to consider while working on my own solver.

[Kim et al. 2018] https://www.researchgate.net/publication/329715304_Real-time_Inverse_Kinematics_Technique_for_Controlling_Redundant_Avatar_Arm

This paper discusses how arm positioning can be solved for in VR using an existing algorithm called FABRIK, which stands for Forward and Backward Reaching Inverse Kinematics. I haven't read through the paper in detail yet, but there are side by side comparisons of the solved pose and the actual user, and the solver uses an additional bone to model the shoulder rather than just using a single joint. It seems like this could a algorithm that I fully implement as a point of comparison in my project.

2.1 Technical Challenges

This project involves addressing the following key technical challenges:

- Creating a test environment in Unity that includes common VR interactions.
- Potentially calibrating the size and proportions of the skeleton to unique users.
- Implementing multiple IK algorithms for estimating the pose of the upper and lower body.
- Animating body geometry procedurally using calculated values.
- Implementing an application that allows for the use and/or direct comparison of the various IK methods implemented.

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2.2 Key Risks and Mitigations

Some of the key risks and potential solutions are as follows:

- I've never used the VIVE trackers before, so difficulty setting them up is possible and could disrupt development. In order to mitigate this, I will want to set them up as soon as they become available to me. Additionally, I will likely reference any tutorials that I can find about using them in Unity so that I can get started with them faster.
- Since the VIVE trackers are required for the project, getting trackers delivered late in the project will leave less time to learn how to use them and develop with them. This risk can be mitigated by restructuring the current schedule to prioritize milestones that don't require the trackers. And if trackers cannot be obtained, the project can be altered to explore heuristics without the trackers, or IK algorithms that would require trackers could be tested with pre-made animations instead of actual user input.
- I don't have any formal knowledge about human kinematics, so I may have to learn about that in order to define good heuristics on rotations while working on this project. This can be mitigated by reading research papers that discuss kinematic restrictions and IK heuristics.

3 HARDWARE AND SOFTWARE

This project requires the following hardware:

- [For Demo] Oculus Rift: I have one available for development due to other projects that I'm working on, but will require one for the demo day. Open to using other headsets for developing and demoing as well.
- [For Demo] Desktop PC: VR capable PCs are avaliable to me for development, but I will require one for the demo day.
- [Requested] VIVE Trackers: at least 2 needed to be able to improve arm tracking or attempt leg tracking. 3 would allow me to experiment with tracking the torso or waist, and 5 would allow me to apply both the improved leg and improved arm IK algorithms at the same time.

This project requires the following software:

- [Personal] Unity: This will be provided by the student team
- [Personal] SteamVR: This will be provided by the student team

4 TEAM RESPONSIBILITIES

This is an individual project, however the tasks can be broken down as follows

- **Terrell Strong**: Responsible for: (1) setting up Unity for VR, (2) implementing IK with headset and controllers positions, (3) incorporating additional trackers into the IK calculations, and (4) developing a simple game in order to test and compare effectiveness of the various IK methods implemented.

5 DEVELOPMENT PLAN

I aim to complete this project over three weeks, with the following major milestones.

- **March 2**: Create and setup the Unity project for VR.
- **March 2**: Create first test environment with simple interactable objects.
- **March 6**: Implement upper body IK models using headset and controllers only.
- **March 9**: Incorporate additional trackers into the upper body IK model.
- **March 9**: (Optional) incorporate collision detection to prevent geometry from intersecting
- **March 10**: Implement a lower body IK model approximating pose without additional trackers.
- **March 13**: Implement lower body IK model using additional trackers on the feet.

- **March 17**: (Optional) Develop a small pose matching game to test and compare IK models.
- **March 18**: Complete and submit the final report.
- **March 19**: Prepare final project demo, including (optional) poster.
- **March 19**: (Optional) Prepare demo video with comparisons.
- **March 20**: Participate in the final project demo session.

REFERENCES

Sanghyun Kim, Junhyung Kim, Ji-Hun Bae, and Jaeheung Park. 2018. Real-time Inverse Kinematics Technique for Controlling Redundant Avatar Arm*.

Pärtel Lang. 2016. Inverse Kinematics in Dead and Buried.