Positional Tracking for Mobile based Virtual Reality Systems

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Problem Description

- Objective: To develop a positional tracking system for smartphone based Virtual Reality(VR) Head Mounted Displays(HMDs), that tracks body movements for user interaction and navigation within the VR environment, with the user walking in place in the real world, to create a naturally immersive VR experience at a low-cost.
- Positional tracking is composed of two parts: Rotation and Translation. It grants the user 6 Degrees of Freedom (X, Y, Z and Up/Down, Left/Right, Top/Bottom). Our project involves translating the actions of a user with very limited physical space in the real world, to dynamic interactions in the VR world.

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Problem Description

- Most existing VR headsets implement rotational-tracking for the head. However, they do not allow navigation(legs) and object interaction/manipulation(hands) within the VR environment.
- The biggest challenges: limited spaces, reduced processing power and latency, less-intuitive input systems.
- While these existing setups may provide a satisfactory experience, these are counter-intuitive and are by no means immersive, which defeats the goals of VR.

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Literature Survey

- Devices like the Oculus Rift incorporate sophisticated head-tracking, but are more expensive when compared to devices like Google Cardboard. However, one roadblock that all of these devices hit is hands-free virtual locomotion and object manipulation.
- Some headsets use controllers or remotes that need to be held, reducing the player's freedom of movement.
- Real-time body-tracking requires high computation power, that cannot be provided by these smartphones.

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Literature Survey

- We were very much inspired by the work of Sra et al.[1], the creators of MetaSpace, social VR system where users can grasp and manipulate objects, walk around in space, and get tactile feedback.
- Metaspace allows walking in physical space by tracking each user's skeleton in real-time. When users touch or manipulate an object in the virtual world, they simultaneously also touch or manipulate a corresponding object in the physical world
- This however requires a one-one mapping of real world objects to objects in the virtual world. This kind of an ecosystem design cannot be generalized for use with other applications.

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Literature Survey

- Specific to this project, for hands-free virtual locomotion, we plan to experiment with the work of Tregillus et al.[2]. Their work, featuring an alternative approach to WIP was published very recently.
- VR-STEP, their WIP implementation, uses real-time pedometry to implement virtual locomotion and requires no additional instrumentation outside of a smartphone's inertial sensors.
- Two phases of their algorithm: Step detection and Virtual locomotion. By modifying their WIP speed, users have precise control over their virtual speed.

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Literature Survey

[1] Sra, Misha, and Chris Schmandt. "MetaSpace: Full-body tracking for immersive multiperson virtual reality."Adjunct Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology. ACM, 2015.
[2] Tregillus, Sam, and Eelke Folmer. "VR-STEP: Walking-in-Place using Inertial Sensing for Hands Free Navigation in Mobile VR Environments."Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems. ACM, 2016.

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Proposed Approach

- Most phones today come with in-built IMU sensors and cameras. These are necessary for positional tracking, but not sufficient. Also, being a resource-intensive implementation, using a phone independently may not suffice.
- PCs with cameras, which are widely available, when coupled with the phone's sensors could help with tracking, reducing the processing load on the phone and allowing a more sophisticated tracking mechanism
- We would begin by experimenting with a client-server setup between the phone and the PC. The phone would act as the VR viewer and tracks WIP, while the PC performs hand tracking. Low-latency is the key.

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Proposed Approach

- As for the tracking mechanism, we need to achieve two main goals: navigation and object interaction/manipulation; independent of any controllers or similar hand-held devices.
- Sensor fusion could be used independently for rotational tracking. For translatory motion tracking, we plan to experiment with the algorithm proposed by the folks behind VR-STEP.
- WebVR, an open-source VR project by Mozilla, would be the platform we would use for this project, as it suits our proposed approach and allows for extensive changes, bottom-up.

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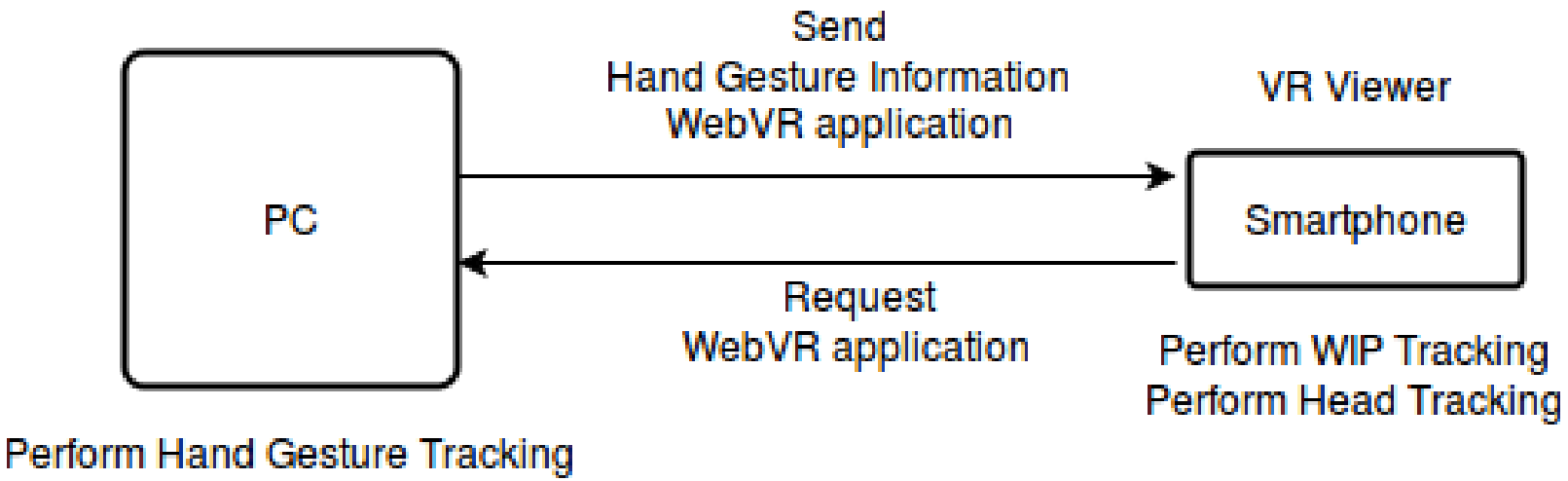
Proposed Approach

- As for object interaction/manipulation, we plan to use hand gesture recognition techniques to achieve the same.
- This needs to happen in real-time, thus a device with more computation power is often necessary.
- At a very basic level, we plan to experiment with contour detection and identifying convexity defects by drawing a convex hull around the hand.

System Diagram



Expected Results

At the end of this project, we aim to build a robust positional tracking system for simple VR HMDs like Cardboard, with the following features:

- Low-latency, low-noise rotational and translatory motion tracking.
- Effective mapping of real-world actions to interactions in the VR world.
- Low-cost, simple to setup solution.

Immersive VR is the future, and this is our first step in that direction.

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