CSCI 5460   Virtual Reality

Name: XXXXX Year: undergraduate year 4   ID: XXXXXXXXX

Survey Report

Topic: Redirected Walking

Paper Selected:

* Mapping virtual and physical reality

SIGGRAPH 2016

* Towards Virtual Reality Infinite Walking: Dynamic Saccadic Redirection

SIGGRAPH 2018

* In the Blink of an Eye: Leveraging Blink-Induced Suppression for Imperceptible Position and Orientation Redirection in Virtual Reality

SIGGRAPH 2018

Notice:

* Originally there is one more paper is selected:

Redirected Smooth Mappings for Multi-user Real Walking in VR

SIGGRAPH ASIA 2019

However, this paper is not focus on redirected walking techniques directly, but based on SAM (Smooth Assembly Mapping) in their previous paper, which similar to “Mapping virtual and physical reality” but changes the static planar mapping methodology to super-patches, building a multi-player system, like collision detection, physical interaction with environment.

Only some redirected walking techniques are touched, i.e. modify little bit of SAM, which is not on this paper

Therefore, I choose to drop this paper as not that relevant to the topic.

In virtual reality, allowing users to walk freely will increase the immersive experience and decrease the discomfort. However, for most of the applications, the virtual environment is bigger than the real environment, which the one-to-one mapping from virtual world to our reality is impractical in most of the cases, especially for those gamers at home. Therefore, many researchers, e.g., the author of the above papers, want to tackle this challenge, creating perception of walking in a large or infinite virtual world within a smaller finite physical space with obstacles (home environment or multiplayer) comfortably. This is an interesting topic and thus, many techniques have been proposed, such as robot tiles, motion carpets, etc. In this survey report, it will focus on redirected walking, which is the most popular technique in gaming and an affordable solution to the public.

In general, there are 2 approaches before 2018: continuous manipulations (dynamically scaling user motion and head rotation for the virtual camera) and warping virtual scene. I will focus on warping, and the new approach proposed in 2018: discrete manipulation.

* Warping Virtual Scene

There are various planar mapping techniques for warping virtual scenes, but usually their goal is to avoid folding.

But in 2016, a custom re-projective rendering method was proposed in SIGGRAPH, named “Mapping Virtual and Physical Reality”. [Sun et al. 2016] , which suggest having proper folding.

Basically, this method creates a distorted mapping of the virtual environment to the physical reality in a way that only a minimal redirection is necessary, by applying nonlinear transformation, magnifying the effective physical space, and then rendering.

The paper motivation is to provide a more general method, or a system to match a given pair of virtual scene and real space.

In details, they suggest that given a 2d floor plan for virtual Sv and real Sr scenes, compute a static forward map first, which is surjective.



They map each virtual scene pixel x = (x,y) to a real scene point u=(u,v). and allowing proper folding of large virtual scenes into small real scenes. The mapping method is similar to planar mappings, they use a basis-function form to facilitate analytical computation of Jacobians and Hessians:

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where bi are basis functions with Gaussians, T is an affine transformation matrix.

Next, the goal is to find proper c = {ci} and T, in the purpose of globally conformal and locally isometric. That means angle preserving globally but distance preserving locally. Angle preservation is done by minimax the energy contribution.



Then for the locally isometric, it requires Jacobians JTJ = 1. This will come up with a constrain





Then, the real space is taken into consideration. It includes exterior boundary constraints (adding a series of linear constraints, line functions B)



where C is the center of physical space;

and an interior obstacle barrier (using 2D Gaussian based barrier function for faster computation.)





After that, this local fold-over may produce visible artifacts,





thus, a local bijective constraint is used in a coarse-to-fine process with relaxed distance constraint, to encourage bending over folding. Due to performance issue, one more constraint has been added:





Combining all the constraints and barriers mentioned before, the constraints are not convex and cannot use QCQP solver (quadratic programming in minimax format), then, an interior-point method is used.

In short, the final static mapping becomes: 

After the static map has been done, it needs to track current user position, using the dynamic inverse mapping.



 It uses Jacobian of the reverse function of our static forward map. Then updates the user(camera)'s direction, position, and orientation for rendering. Then, it comes up with another issue: handling occlusion.



As the virtual scene has been distorted or folded, some scenes will show ghost objects blocking. The paper suggests an accurate method: for each fragment visible in real scene but not in virtual scene, find the nearest fragment visible in virtual scene, then assign the 3d Euclidean distance between virtual and real fragments as the depth value of real fragment for rendering real image. For more robust dis-occlusion, use four instead of one nearest visible fragment.

In addition, during implementation, the algorithm above will cause wrong skybox (far-away objects will be rendered into background), so an environment map is used.

Finally, the algorithm is done, and the equations above can have a meta parameter G(w) = Gx. G(0) = virtual scene, G(1) = real scene with the algorithm.

This w parameter and some scalar in equations will be experimented by participants and find out the most comfortable data.

However, there are some limitations, like it only goods for 2d maps, and cannot handle a large area that is entirely dis-occluded, large open virtual spaces cannot be folded into a small real space without being noticed by users, this will affect some game level design process. In addition, the game shall not have teleport around the same scene otherwise the static map shall be useless, and thus it cannot combine with discrete manipulation mentioned later.

 And in my opinion, I don’t think there is anyone accepting distorted maps, the participant amount is not enough. Imagine you are playing fps, the straight road is distorted and blended, how to give a shot to your enemy? Does the bullet turn its direction?

1. Discrete Manipulation

First, “Change Blindness” has to be introduced before anything about discrete manipulation. Change blindness means an inability of the human biological visual system, that we cannot notice significant changes to visual scenes during visual interruptions by humans himself, such as blinking, saccades.

According to lots of experiments and theories, the human visual system uses a built-in prior assumption that the world is stable during eye movements. Therefore, the perception of displacements of the scene during change blindness is suppressed, that means the thresholds for the detection of a displacement of the current retinal image are elevated. Thus, this provides another approach manipulating the virtual camera, but this requires eye-tracker.

2.1. Saccadic Redirection

“Towards Virtual Reality Infinite Walking: Dynamic Saccadic Redirection”

This paper motivation is to try the new approach for solving the mapping problem: saccadic. In general, this is a dynamic approach, which can avoid static or dynamic obstacles in the real world. There will be redirection or reorientation during saccadic. To induce more saccadic, subtle gaze direction (SGD) will be used. The algorithm is divided into 3 parts, before each frame, it detects saccades, then it performs path planning (amortized over 2-5 frames), after that, performs the redirection with subtle gaze direction, finally rendering.

* Detection of saccadic is done by high-speed- eye-tracker with a camera reorientation thresholds, which is found by other papers.

* Dynamic pathfinding can guide users away from stationary or moving obstacles in real worlds, by using dynamic sampling methods. This is an importance-based-real-time sampling mechanism, emphasizing areas that are close to the user's current position, and areas in the user's camera frustum for predicting near future.





The static boundary avoidance will also be considered with a soft barrier function from another papers, ,



The dynamic obstacles has a similar approach,





Given the energy term above, optimal redirected mapping is defined.



* Subtle gaze directions are used for increasing user’s saccades so that it could have redirection. There are two approaches: image-space, object space.

Image-space involves modulation to pixels in a user’s visual periphery.

Object-space involves modulation on textures or materials of chosen virtual objects.

After implementing this algorithm, it has a user study on comfortability (compared to other methods)and an error measurement.on the area outside physical space or inside an obstacle.



There are only a few failing cases, around 6% participants have collided with dynamic obstacles. The results are extremely good that it seems to have no limitation except money issues, as it requires a high demand on eye tracker with ultra performance, and low-latency gaze data at circa 2000Hz refresh rate or more. But the paper said it can be faster and more powerful with AI.

2.2. Blink

“In the Blink of an Eye: Leveraging Blink-Induced Suppression for Imperceptible”

The motivation is similar to the previous one. However, the paper does not implement the blinking redirection methods to a scene and tested on any dynamic obstacles.

The paper focuses on psychophysical experiments and analyzes human sensitivity to subtle translation, rotation induced, and the reorientation during eye blinks. After analyzing all the data, finding out those threshold, it explains the eye blinks methodology can be used for perceptually-inspired locomotion techniques in VR. It could be a supplement technique for traditional RDW, by improving the bending gains.

1. Opinions

After researching these papers, I find them all are interesting ideas. The warping methods can be used without eye-tracking, which is more affordable by the public, but the scene will be distorted and some implementation issues are left, that means it needs extra effort for game level creators to avoid all these problems. Personally speaking, the distorted scene shall be an extra problem to motion sickness as that is unreal, I think it should be favored in unrealistic puzzle solving games.

The discrete manipulation methods seem to be great, but it requires eye-tracker. Although the ultra-high performance of saccadic redirection has a really high requirement at the same time, I believe that it could be combined with the blink redirection and become the trend in the future.

Reference

* Mapping virtual and physical reality

<https://www.researchgate.net/publication/305217688_Mapping_virtual_and_physical_reality>

SIGGRAPH 2016

* Towards Virtual Reality Infinite Walking: Dynamic Saccadic Redirection

<https://research.nvidia.com/sites/default/files/pubs/2018-08_Towards-Virtual-Reality/paper_0.pdf>

SIGGRAPH 2018

* In the Blink of an Eye: Leveraging Blink-Induced Suppression for Imperceptible Position and Orientation Redirection in Virtual Reality

<https://basilic.informatik.uni-hamburg.de/Publications/2018/LSLWB18/eye_blinks.pdf>

SIGGRAPH 2018