Laplacian Vision:
Augmenting Motion Prediction via Optical See-Through Head-Mounted Displays (OST-HMD)

Yuta Itoh, Jason Orlosky, Kiyoshi Kiyokawa, Gudrun Klinker

Augmented Human 2016
Naïve Physics (Hayes et al. 1978):

our untrained perception of basic physical phenomena

Photo: Steve-65
In daily life...

Photo: AEQWF
Naïve physics is, however, imperfect

http://www.failepicfail.com/
In Science Fiction, a precog sees his short-term future...

*Next*, Nicholas Cage, TM & © Paramount (2007)
…or brain implants enable you to **calculate** it

*Jump 225 Trilogy*, David Louis Edelman, 2006-2010

*Wizard’s brain*, Reiichi Saegusa, 2001-present
Laplace's demon: a causal determinism

If the Demon knows the precise location and momentum of every atom in the universe, their past and future values for any given time are entailed; they can be calculated from the laws of classical mechanics.

*Essai philosophique sur les probabilités*, Pierre-Simon Laplace, 1814
**Laplacian Vision:** A vision augmentation system to assist motion prediction.

Shot directly through the system

User-view camera

Optical See-Through HMD
Related work: projection mapping

- Projector: Koike & Yamaguchi, AH’15
- Custom DLP projector: Charette et al., ICCP’12
- Saccade Mirror: Okumura et al., ICME’12
Related work: human vision enhancement

Field of view

Orlosky et al. TVCG’15

Eyesight

Itoh & Klinker AH’15

X-ray vision

Avey et al. VR’09
Related work: “Aftermath” (AR + physics prediction)

Leigh & Maes CHI’15
A proof-of-concept system

Tracking system

Flying ball

Virtual Image plane

OST-HMD

User-view Camera
A proof-of-concept system

Tracking system

Flying ball

Virtual Image plane

OST-HMD

User-view Camera
Future path estimation of a flying ball in **real time**
Calibrated HMD rendering matrix to the viewpoint
Example 1
Example 2
Example 3
User study: a fall-point **prediction game**

29 subjects * 5 launches * **with/without**

With Laplacian vision

Without (i.e. the naïve vision)
**Video Length** conditions

29 subjects * 5 launches * with/without * 3 lengths
View Angle conditions

29 subjects * 5 launches * with/without * 3 lengths * 3 angles
Result: 3x accuracy improvement

Bird’s-eye view
Summary

- Assisting our \textit{naïve physics} skill
- \textbf{Optical See-Through} HMDs with a real-time AR rendering
- Simulating the \textit{physical behavior} of the user’s environment
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Human x OST-HMD x Physics

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Appendix
Latency diagram

**System A**
Tracking (2x ARTTRACK2)

IR image (60Hz)

3D position of the ball (60Hz)

~19 ms latency

~80 ms latency

Real world

Target ball

**System B**
Prediction & Rendering (Unity 3D)

OST-HMD (nVisor ST60)

~80 ms latency

Displayed image (60Hz)

Observer (User-view camera)
Forward prediction

100 ms forward prediction

No prediction

Real ball carrying
HMD Display Calibration

Eye
(a user-view camera)

Virtual Image

World
Single Point Active Alignment Method (SPAAM) [Tuceryan ‘00] [Genc ‘02]

Align a 3D point in the scene to 2D screen points

A.R.T tracking system
Hardware