Engaging virtual reality for transport planning
Applications in Singapore

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Engaging Virtual Reality for Transport Planning Applications in Singapore

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Prof. Dr. Hölscher (Co-PI)
ABOUT THE FUTURE CITIES LABORATORY

Singapore ETH Centre
- ETH Zurich’s first major research centre outside Switzerland
- Part of CREATE Campus with many other international universities: MIT, Berkeley, Cambridge, TUM...

Future Cities Laboratory
Create knowledge and ideas for a sustainable urban future
- Through science, technology and design
- Disciplinary expertise and transdisciplinary projects
- In place in partnership and dialogue with local stakeholders
We can't address current and future urban mobility challenges alone and don't act in an ivory tower. Therefore, our core principles are Open Source and engaging with local stakeholders and communities.

Given today's highly specialised work and research environment, we believe in the power of working in an interdisciplinary manner.

Engaging Mobility combines cutting edge technologies with state-of-the art methods in innovative research projects.
From Clementi to CBD in 62 minutes (2016) The Straits Times. Available here

CYCLING EXPERIENCE IN SINGAPORE: OFF STREET

THIS IS WHAT IT'S LIKE TO CYCLE
CYCLING IN SINGAPORE: FUTURE PLANS

New cycling path, more greenery and recreational facilities

At Pedestrian Priority Zone, cyclists slow down or dismount and push

Source: URA
Objective
To understand what is needed to make cycling viable modes of transport in Singapore
Explore VR as a research tool

Methods
Combine science, technology and design
Virtual Reality experiments
Stated preference surveys

Outcomes
Evidence-based street design recommendations
Virtual reality as a tool for transport planning

Engaging Active Mobility, Seng Poh Road (2016)
Introduction

Expert survey on cycling in Singapore

Generating and animating 3d streetscapes

Bike to to Future I

Bike to the Future II

Bike Pulse

Bike to the Future III

Source: Tanvi Maheshwari
WHY ARE CYCLING ACTIVITIES SO LOW IN SINGAPORE?

Method
Expert interviews
Approx. 1 hour
Semi-structured
13 respondents from
government, research,
commuters & advocacy groups

Evaluation by ranked sum;
Experts were asked to state why
people are not cycling, first
mention received 0.5 points,
second mention 0.3 points, third
mention 0.2 points.
CYCLING IN THE NETHERLANDS

Michael van Eggermomd (2016)
Kruisstraat, Eindhoven, the Netherlands
Introduction

Expert survey on cycling in Singapore

Generating Virtual Reality for cycling research

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Bike Pulse

Bike to the Future III

Source: Tanvi Maheshwari
WHY VIRTUAL REALITY?

Holistically understanding behaviour
Built environment influences perception of safety, comfort and pleasure
Challenges with cross-sectional and longitudinal surveys
Stated preference surveys for inexistent transport options, but limited reliability if people don’t have any actual experience with it.
VR allows you to compose virtually any environment

How to create realistic experience?
• Eye Level Perspective
• Sense of place
• What can you see (sightlines), and who can see you (multiple agents)
• Speed, volume, proximity of moving traffic
• Idea of time? (slow spectator vs. fast spectator)
• Audio feedback
• Temperature and humidity
• Effect of topography
Traditional surveys

SURVEYS

Using images

Erath, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) “Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.”, Transportation Research Record

Using Virtual Reality

Heilig’s Sensorama. Retrieved from Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research
VIRTUAL REALITY AS A RESEARCH TOOL

Research questions

How to employ virtual reality for research
Reproducibility of real field observations
Limitations of VR in research
How can sensors of physical reactions enhance survey methods?
WORKFLOW

01 STREETS

02 TRAFFIC

03 GAME ENGINE

04 VIDEOS

05 VIRTUAL REALITY

06 IMAGES

INPUT

OUTPUT
**Procedural modelling**

- Computer graphics technique to create 3D models and texture from a set of rules
- Programmable visualisation saves a lot of modelling efforts
- Interactive rendering allows new applications

**Complete streets rule**

- Developed by ESRI Research
- Robust procedural street example that incorporates knowledge and ideas from various sources of transportation planning knowledge
- We further developed those rules to fit Singapore conditions and our modelling needs.

Code available at

https://github.com/fcl-engaging-mobility/Complete_Street_Rule
GENERATING IMAGINARY STREETS
Challenges:

- Import of geometry
- Interaction of pedestrians and vehicles
- Modelling of cyclists
- Human (unpredictable) behaviour
- Rendering and video quality in 3D
- Shared space between pedestrians and cyclists
- Interface between Vissim and Unity3d
**IMPROVING THE 3D ENVIRONMENT: FROM VISSIM TO UNITY**

Output file with vehicle trajectories from Vissim (2016) Source: Jonas Kupferschmid

Prototype of virtual cycling environment Source: Michael Joos (2016)
PUTTING ALL TOGETHER

City Engine

Input
- City Engine: procedural city 3D models
- Vissim: vehicles, cyclists, pedestrians and lights simulation data
- Other 3D models: vehicles, pedestrians, street furniture, traffic lights, etc.

Vissim

3D Models

Output
- High visual quality renderings for presentations and surveys
- Videos of moving traffic in 3D environment.
- 360 videos for immersive VR experience
- Interactive VR application with real-time traffic reaction

Still images

Videos

Interactive VR
PUTTING IT TOGETHER: SCRIPTS

Traffic Data
- Interpret Vissim's traffic data
- Traffic lights system
- Traffic diversity generator

Animation
- Pedestrian adaptive movement
- Vehicle trajectory smoothing
- Vehicle brake lights
- Vehicle wheel rotation
- Animated cyclist

Code available at
https://github.com/fcl-engaging-mobility/UnityScripts
SOME PAPERS AND BLOG POSTS


Kupferschmid, Jonas and Alexander Erath (2016). ‘How to Model Pedestrians and Cyclists Interactions with out-of-the-Box Features of Vissim? Engaging Mobility Blog.'
Introduction

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Bike to to Future I

Bike to the Future II

Bike Pulse

Bike to the Future III
BIKE TO THE FUTURE I

**Explore** how to use VR as a research tool

**Redesign** three streets around Tiong Bahru Market to accommodate cycling infrastructure.

**Invite** people to cycle on these three different streets designed for active mobility in Virtual Reality

**Engage** and get feedback on how safe and comfortable they feel cycling given the new design.

**Leverage** on existing 3D models and Park(ing) Day
TIONG BAHRU: TRAFFIC CIRCULATION

Current

New design
DESIGN: STREETS

Lim Liak Street

Current

3D rendering with traffic

New design with traffic

Kim Cheng Street

Seng Poh Road
<table>
<thead>
<tr>
<th></th>
<th>Date</th>
<th>Event</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16 Sep 2016</td>
<td>Park(ing) Day</td>
<td>Tiong Bahru</td>
</tr>
<tr>
<td>2</td>
<td>5 Oct 2016</td>
<td>Archifest</td>
<td>Raffles Place</td>
</tr>
<tr>
<td>3</td>
<td>19-21 Oct 2016</td>
<td>SITCE Conference</td>
<td>Suntec Convention Center</td>
</tr>
<tr>
<td>4</td>
<td>26 Mar 2017</td>
<td>Car-free Sunday</td>
<td>Telok Ayer Street</td>
</tr>
</tbody>
</table>
BIKE TO THE FUTURE I – UNEXPECTED MEDIA ATTENTION

Using virtual reality to get more people to cycle

Using virtual reality to envision a car-lite future
You can watch the video [here](#).

Use Google Card Board for a VR experience.
**SURVEY DESIGN**

**Pre-survey**
- Sociodemographics
- Habits and attitudes towards cycling
- Willingness to cycle with today’s infrastructure

**VR-Experiment**
- Think aloud protocol (What do you see?)
- Physical reactions (pedalling, steering, turning head, braking)

**Post-survey**
- Willingness to cycle with new infrastructure
- VR Experience (realism, motion sickness, comfort, excitement)
Traditional surveys

Using images

Using Virtual Reality

Erath, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) “Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.,” Transportation Research Record

Heilig’s Sensorama. Retrieved from Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research
Descriptive statistics

Age pyramid

Residence status

Cycling commute

Cycling leisure
RESULTS – WILLINGNESS TO CYCLE

**YES, I would consider cycling on this road**

Before

- 65%
- 59%

After

- 81%
- 93%
RESULTS – WILLINGNESS TO CYCLE

**YES, I would consider cycling on this road with a 10 year old**

- **Before:**
  - 10%
  - 44%
  - 11%

- **After:**
  - 74%

Images showing the road before and after improvements.
RESULTS – VIRTUAL REALITY EXPERIENCE

Did you experience the following?

<table>
<thead>
<tr>
<th></th>
<th>Not at all, slightly</th>
<th>Somewhat</th>
<th>Somewhat</th>
<th>Yes!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excited</td>
<td>14%</td>
<td>32%</td>
<td>55%</td>
<td>60%</td>
</tr>
<tr>
<td>Realistic</td>
<td>42%</td>
<td>62%</td>
<td>43%</td>
<td>37%</td>
</tr>
<tr>
<td>Comfortable</td>
<td>32%</td>
<td>62%</td>
<td>43%</td>
<td>55%</td>
</tr>
<tr>
<td>Motion sickness</td>
<td>42%</td>
<td>43%</td>
<td>55%</td>
<td>60%</td>
</tr>
</tbody>
</table>
'Pedestrians interacting with bicyclists'

'Realistic feeling that pedestrians were about to walk in my way'

'Good design of surroundings in 3D. Pedestrians are not paying attention to me'

'Simulation'

'That the brakes didn't work was very irritating.'

'Steering was hard'

'Brakes not working'

'Design'

'The new bicycle lane is very good for cyclists. I like it very much. It reduces conflict between types of commuters.'

'Pleasant experience to see a car free area that will ultimately be greener, less polluted and more kids/people friendly.'

'Three different designs give us different ideas and impressions. Good experience. Thank you. Personally I prefer segment 2.'
FINDINGS

VR really helps to communicate the experience of future street designs
• Better sense of place
• Respondents naturally look around
• Plenty of physical reactions
• Creates excitement and a lot of media attention

Limits of VR
• Tremendous amount of work
• People get motion sick
• Tremendous amount of work
• Time intensive
• 360 video is not enough for immersive experience

On which level you try to understand cycling behaviour?
• Willingness to cycle
  -> stated preference probably better suited
• Perception of safety, comfort and pleasure
  -> Behavioral reactions rather than survey
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Bike to the Future II

Bike Pulse

Bike to the Future III

Source: Tanvi Maheshwari
MEASURING SAFETY, COMFORT & PLEASURE

Motorists volume & speed
Cyclists volume & speed
Pedestrians
Traffic mix
No. of lanes
Side roads
Lane markings
Separation
Width of bicycle lane
Motorists’ behavior
Cyclists’ experience

Traffic Flow

Infrastructure

Cognitive load
Cycling in company
Being able to talk in company
Scenery

Pleasure

Safety

Comfort

Environment

Noise level
Temperature
Wind
Shade
Slope of the road
Continuity of bike lane
Maintaining momentum
Surface of the road
Presence of bus stop(s)
Network connectivity

Feasibility with Bicycle Simulator
BIKE TO THE FUTURE II

**Aim**
Measure cyclists’ perception of safety, comfort & pleasure in a controlled environment

**Methodology**
Development of interactive cycling simulator
Test impact of various stressors and mitigation strategies
Trigger traffic events (conflicting traffic)
Sensing of physical reactions (head movement, pedalling, steering, braking)
Before / after experiment surveys

**Outcomes**
Insight in the perception of safety for different design options
Evidence-based design guidance
Realizing strength and limitations of using virtual reality
**EXPERIMENT SETUP**

**Research questions**

Which distance and separation to vehicles works best is needed to feel safe?

Any differences of perception in VR with regards to speeds, (passing) distance, noise

Can we observe the same physical reactions in VR as in reality?

**Experiment Design**

2 Road types
- 4 lane, bi-directional
- 2 lane, bi-directional

Treatments:
- Traffic
  - Speed
  - Volume
  - Mix
  - passing distance
- Separation
  - None
  - Paint
  - Planter
  - Poles
- Conflicting traffic

Road segments stretch over about 700m

Warm-up cycling with out traffic (3-5min)

**Measurements**

Physical reactions:
- Head movement
- Steering
- Braking
- Pedalling
- Cognitive load
- Reaction times (incoming traffic)
- Cycling speed

Pre-/post survey
- Experience with cycling
- Attitudes
- Stated levels of safety, comfort, pleasure

![Divided two-ways (4 lanes)](image)

![Undivided two-way roads (with parking)](image)

Code available here: https://github.com/fcl-engaging-mobility
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Bike Pulse

Source: Tanvi Maheshwari
Inspiration & Vision

Web-based survey inspired by MIT Place Pulse project

Parametrically generating hundreds of relevant street design configurations

Testing it from different view angles (pedestrian, cyclist, bus driver, car)

Choice modelling

Bike Pulse

Which road feels safer?

This one  That one

Which route do you prefer?

10 min  7 min
Our children need to ride here??

Trucks and cars!

Dangerous design!!

We demand bicycle lanes!

We demand bicycle lanes!
THE HARDWARE

Steering

Tilting

Pedalling

Acceleration / Braking

Traditional surveys

Using images

Using Virtual Reality

Erath A, M.A.B. van Eggermond, S. Ordonez, K.W. Axhausen (Forthcoming) “Introducing the Pedestrian Accessibility Tool (PAT): Open Source GIS-Based Walkability Analysis.” Transportation Research Record

Heilig’s Sensorama. Retrieved from Theory and Research in HCI: Morton Heilig, Pioneer in Virtual Reality Research
Virtual reality headset
S$1,000
Computer
> S$2,000

Virtual reality headset
S$180
Smartphone
> S$400

Virtual reality headset
S$2
Smartphone
> S$200
Procedural modeling

CityEngine (CE)

* COLLADA

3D model in .FBX or COLLADA format

WIP @ FCL CIVIL

SKETCHUP

SKP static model for visual reference

JPG as background image to trace road network

DWG of section plane

Edit CE model in Sketchup to add intersections

UNITY

WIP @ FCL CIVIL

RENDERING & INTERACTION

AUTOCAD

DWG of sidewalk

FZP/PP parser

Realtime simulation update

VISSIM

Use CE geometries in VISSIM for obstacles and roads with Python

Traffic micro simulation

CityEngine uses a third-party library for Collada export where multi-texturing is not compatible with the collada standard