Presentation

Engaging virtual reality for transport planning
Applications in Singapore

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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.
CYCLING EXPERIENCE IN SINGAPORE: OFF STREET

From Clementi to CBD in 62 minutes
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
ENGAGING VIRTUAL REALITY

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
**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 Eggermond (2016)
Kruisstraat, Eindhoven, the Netherlands
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Bike to the Future I

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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

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
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 OF STREETS

**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](https://github.com/fcl-engaging-mobility/Complete_Street_Rule)

ESRI CityEngine (2016)
Source: ESRI
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

**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.

**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
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


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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

- Bicycle network
- Pedestrian network
- Pedestrian area
- Bus stop
<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>
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<td>3</td>
<td>19-21 Oct 2016</td>
<td>SITCE Conference</td>
<td>Suntec Convention Center</td>
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<tr>
<td>4</td>
<td>26 Mar 2017</td>
<td>Car-free Sunday</td>
<td>Telok Ayer Street</td>
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</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
360 DEGREE VIDEO

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
- Willingess to cycle with new infrastructure
- VR Experience (realism, motion sickness, comfort, excitement)
**SURVEYS**

**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

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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%

74%

After
Did you experience the following?

- **Excited**: 60% Yes! / 37% Somewhat / 5% Not at all, slightly
- **Realistic**: 55% Yes! / 43% Somewhat / 2% Not at all, slightly
- **Comfortable**: 32% Yes! / 62% Somewhat / 7% Not at all, slightly
- **Motion sickness**: 14% Not at all, slightly / 43% Somewhat / 42% Yes!
'Steering was hard'
'Brakes not working'

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

'The new bicycle lane is very good for cyclists. I like it very much. It reduces conflict between types of commuters.'
'Three different designs give us different ideas and impressions. Good experience. Thank you. Personally I prefer segment 2.'

'Most memorable experience'

Simulation

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'

Hardware

'That the brakes didn't work was very irritating.'
'Steering was hard'
'Brakes not working'

Design

'That I was not competing with cars for road space'

Personal

Realistic feeling that pedestrians were about to walk in my way'
Good design of surroundings in 3D. Pedestrians are not paying attention to me'

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

Pleasant experience to see a car free area that will ultimately be greener, less polluted and more kids/people friendly.
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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Source: Tanvi Maheshwari
MEASURING SAFETY, COMFORT & PLEASURE

Feasibility with Bicycle Simulator

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

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

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

Infrastructure

Behaviour

Scenery

Cycling in company

Being able to talk in company

Environment

Infrastructure

Behaviour

Cycling in company

Being able to talk in company

Environment

Infrastructure

Behaviour

Cycling in company

Being able to talk in company

Environment

Infrastructure

Behaviour

Cycling in company

Being able to talk in company

Environment

Infrastructure

Behaviour
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)

Undivided two-way roads (with parking)

Code available here: https://github.com/fcl-engaging-mobility
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Source: Tanvi Maheshwari
BIKE PULSE

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
Team

Dr. Alex Erath
Project Leader

Prof. Dr. K. Axhausen
Co-PI
Transport Planning

Prof. Dr. C. Hölscher
Co-PI
Cognitive Psychology

Michael v. Eggermond
Senior Researcher
Spatial Analysis

Tanvi Maheshwari
Researcher
Urban Design

Jonas Kupferschmid
Researcher
Traffic Simulation

Filip Schramka
Hardware genius
Game developer

Mohsen Nazemi
PhD Researcher
Traffic Simulation

Michael Joos
Senior Software Engineer
Gaming Developer

Prof. Dr. D. Schaffner
Psychologist
Cognitive experiment
Our children need to ride here??

Trucks and cars!

Dangerous design!!

We demand bicycle lanes!
THE HARDWARE

Steering

Tilting

Pedalling

Acceleration / Braking

SURVEYS

Traditional surveys

Using images

Using Virtual Reality

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

Game engine: rendering & interaction