AutoBikes: Autonomous Electric Bicycles for First and Last-mile Mobility on Demand

SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN

motion, energy, and control laboratory

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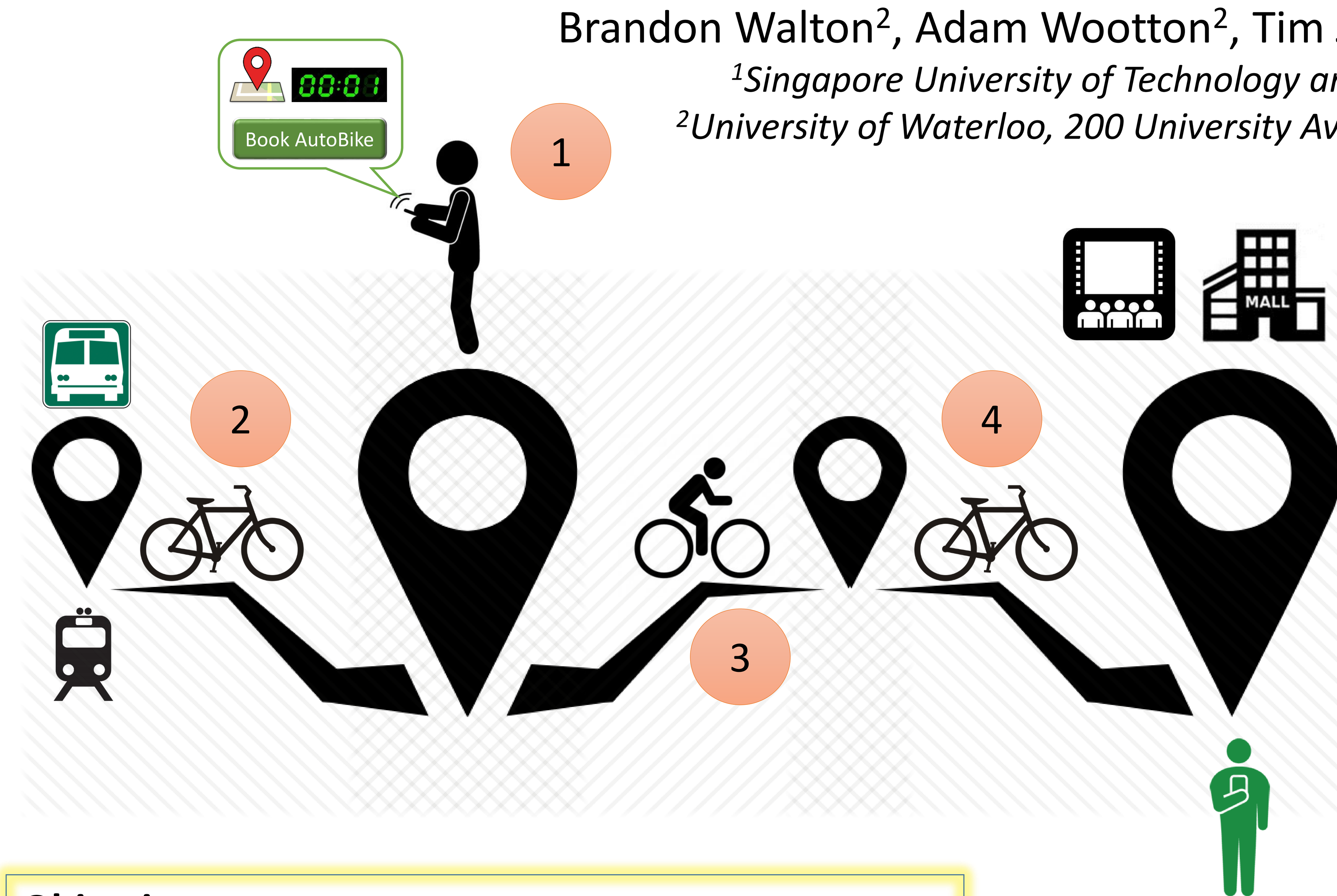
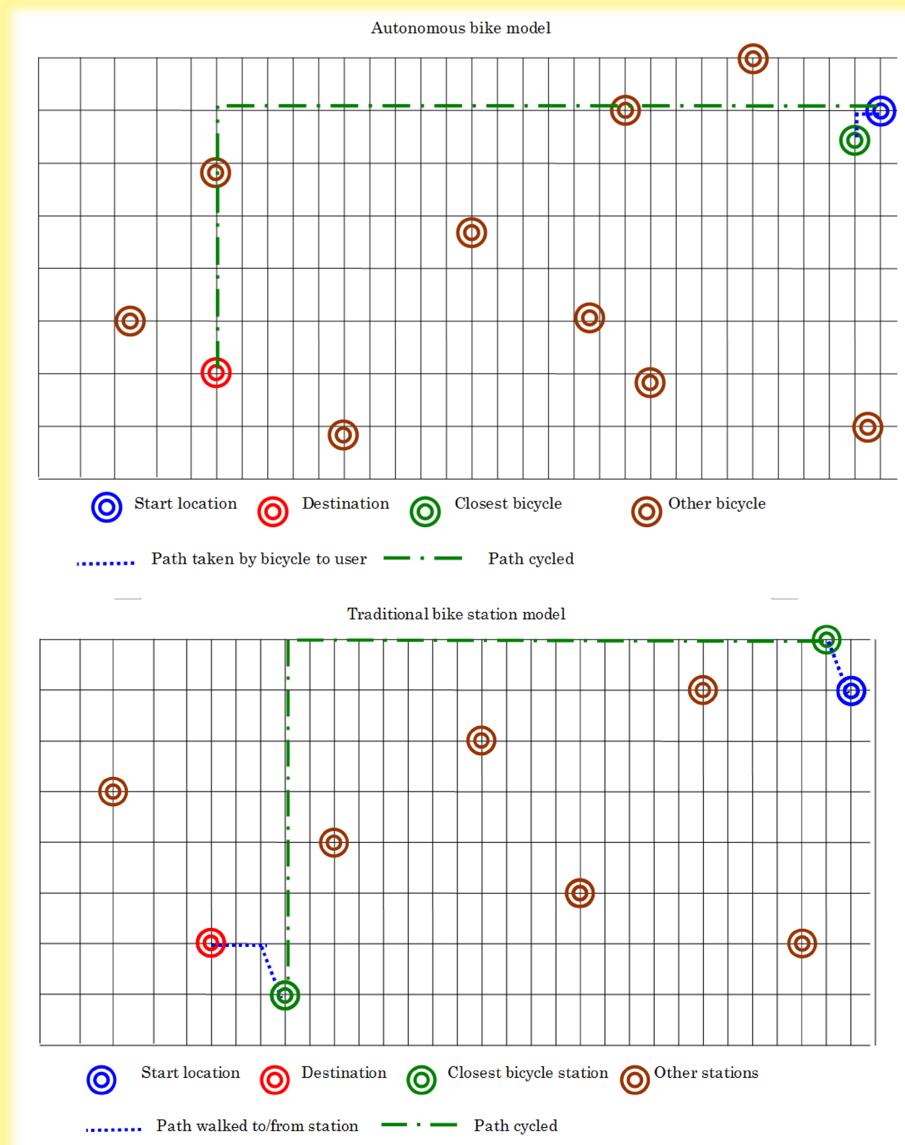
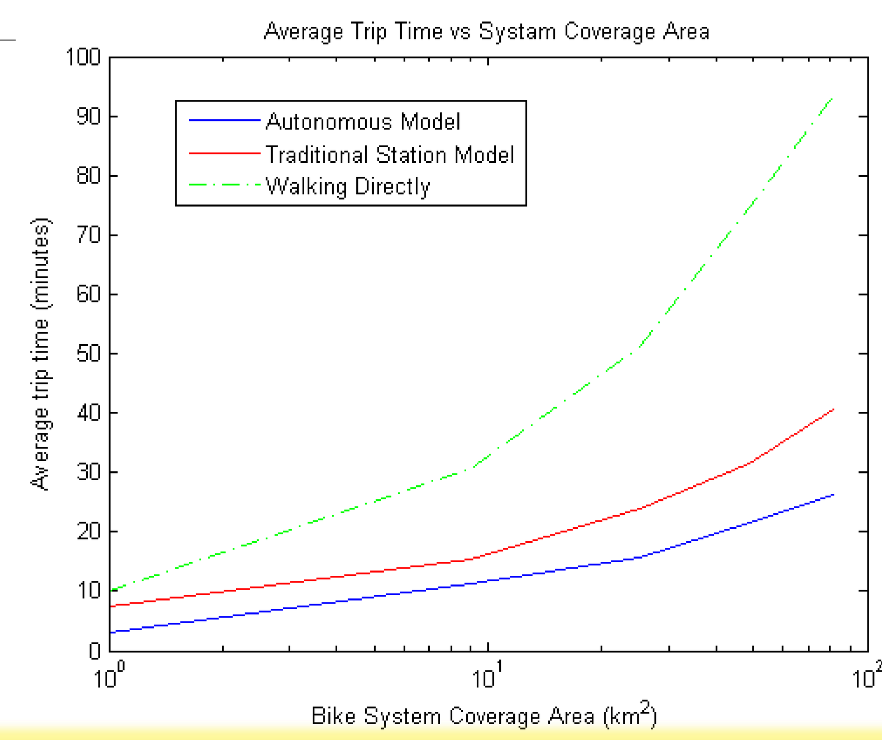


Rebalancing & Business Models



Comparing standard station-based MoD systems & autonomous bike model, greater impact on reduced travel time with greater system area.

Feasible in densely populated areas & in those where traditional systems are impractical.



Objectives

Solve problems faced in urban bicycle sharing systems by:

- Fleet rebalancing to optimally serve demand with supply in real-time
- Reducing the cost and footprint of sharing station infrastructure
- Decreasing costs of damage & theft

AutoBike technology enables bicycles to cruise autonomously while rider-less (recognize road boundaries & avoid collision) and provide route guidance and rider monitoring while ridden.

Can be automatically rented via RFID cards either on-the-fly, or via pre-booking on a smartphone

Only marginally more expensive than standard electric bicycles.

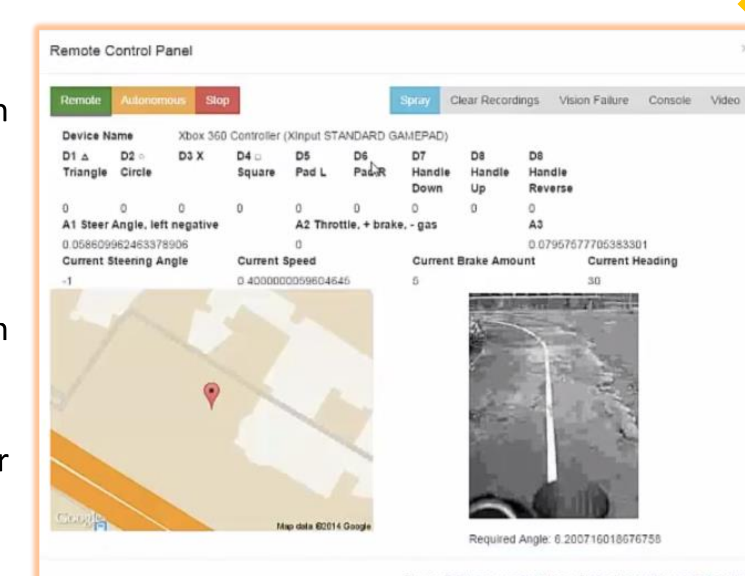
Front-end User Interface & Tele-operation

Front-end user interface provides:

- Choice of mode of operation (autonomous/RC)
- Video feed from the bike
- Location of the vehicle on a map

Automatic prompt for human intervention if vision system fails.

Record human actions for later guidance.



RC & Path-marking commands >>

Socket.io

<< Video, Location & Status msgs.

Server Control System

Node.js-based server platform

Active latency checking to trigger relevant fail-safe mechanisms in case of failures

High level route planning utilising spline interpolation between the GPS waypoints.

Dynamic model simulation for dead-reckoning

<< GPS Way-points | Socket.io/ WebRTC | Odometry & Position >>

Steering

Torque requirement is 6.2 N-m

The prototype shown consists of:

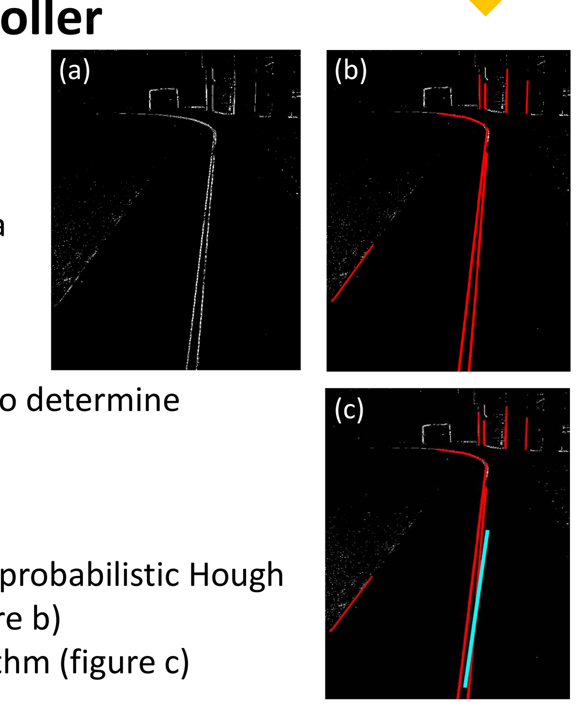
- Electromagnetic (EM) clutch
- Bevel gear train (2:1 speed ratio)
- Worm gear motor (12V DC, 60 W)

Steering accuracy is 12 degrees at 30 degrees/s steering speed

Feedback is from an absolute rotary encoder connected to the steering column by belt & pulley.

Supervisory Controller & Vision System

Android phone with camera running a custom app.



OpenCV image processing to determine Safe Operating Envelope:

- High-pass filter (figure a)
- Canny edge detection & probabilistic Hough line detection filter (figure b)
- Modified RANSAC algorithm (figure c)

Decision tree voting structure to determine bike direction, overall control system by a feed-forward model

<< Speed & Heading | UART Serial | Response msgs. >>

Propulsion & Braking

250 W brushless DC hub motor on its front wheel

Autonomous operating speeds limited to 4-5 km/h for safety concerns.

Autonomous Braking by a separate cantilever braking system operated by an electric linear actuator (23 N peak force)

Max. deceleration around 0.09 G on planar roads.

Wheel Retraction & Path-marking

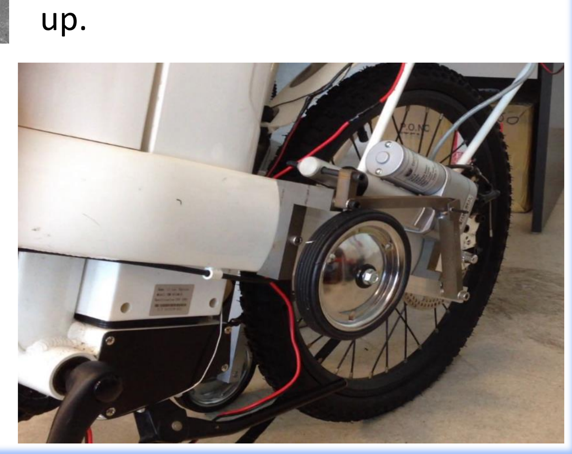
Modified aircraft landing gear mechanism by a linear actuator (489 N peak force, 2-inch stroke) for wheel retraction.

Picture below shows wheels lifted up.

For localization, deposit UV markings on roads.

Sensed with a second image sensor.

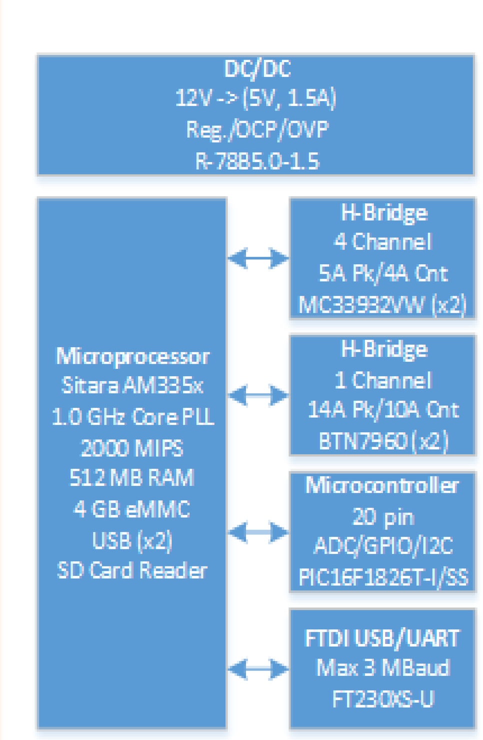
Automatic or manual deposition through a set of selectable stencils to encode information.



<< Power & commands to actuators

Sensor signals >>

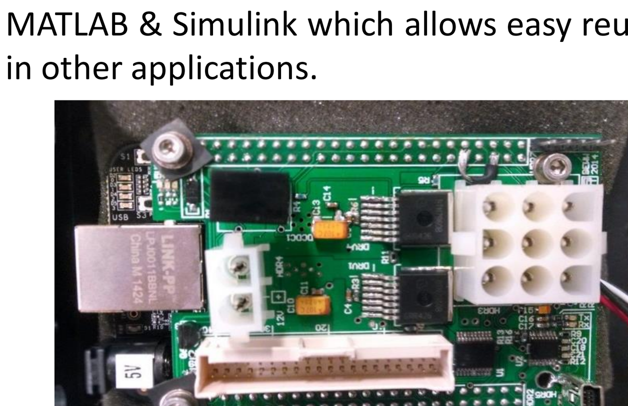
Low-level Controller



TI AM335x series processor packaged in the BeagleBone Black

Running 'bare-metal' for higher level of determinism & executes in hard real-time at 1 kHz with boot times well under 2 seconds.

Low-level controller code authored in MATLAB & Simulink which allows easy reuse in other applications.



Conclusion & Future Work

The bike is fully remote-controllable and is able to follow lanes autonomously now. Work on obstacle detection & collision avoidance and recognition of traffic lights & symbols is in progress. Further on, the following are planned:

- Automatic recovery mechanism in case of vehicle roll-over
- Self-stabilized operation (i.e. retract the supporting wheels) at higher speeds
- Extending the application to 3-wheeled e-scooters & implement in SUTD campus

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