International Public Works Conference
25 -29 August 2019

Robot Walking School Bus Following Painted Lines

E. Lascaris[1], K. Ma[3], M. Teh[3], P. Spicer[3], M. Cullen[3], E. Zane[3], R. Sekhri[3], D. Holmes[3], L. Holmes[3], C. Kappe[3], A. Jain[3], J. Welsh[3], N. Welsh[3], K. Bland[3], R. Tricker[2], M. Johnson[2], B. Harries[2], S. Chetwynd-Brown[1], B. Byrne[1], P. Ali[1].

[1] *Waste and Recycling Team, City of Whittlesea, Melbourne, Australia*
[2] *City Design and Transport, City of Whittlesea, Melbourne, Australia*
[3] *Makers Club, Mill Park Library, Melbourne, Australia*

[*] *Corresponding author. Email: edmond.lascaris@whittlesea.vic.gov.au*

ABSTRACT: *Children today have less freedom to move around outdoors in comparison to previous generations. Anecdotally, this behaviour change is associated with the perceived risks associated with hazards such as street crime and high speed vehicular traffic. As a result of a sedentary lifestyle, children are becoming less healthy – both physically and mentally. In the near future, the development of self-driving vehicles may help to alleviate traffic congestion, but it is uncertain if these vehicles will encourage more students to walk and ride to school.*

Students from the Mill Park Library Makers Club have developed a Robot Walking School Bus to guide students safely to and from school. The Robot is designed to follow a painted line on the footpath. The Robot can also help students collect street litter and transport organic waste from home to school for composting.

This Robot was designed, built and coded by school students and represents a unique student-led approach to infrastructure development for local government. As a consequence, the ideas and concerns of children are more fully integrated in this project, based on their perception of key sustainability and inclusivity issues. Unlike other self-driving vehicles, this robot aims to use footpath infrastructure rather than roads. The original inspiration for the Robot was based on a line-following battery powered train in China. By involving students more directly in infrastructure projects it is hoped that new visions for smart and sustainable cities can emerge that better represent the aspirations of our youth.

KEYWORDS: robot, autonomous vehicle, footpaths, sidewalk, pavement, walking school bus, obesity.

1 Introduction

1.1 Self-driving Vehicles

Self-driving road vehicles are predicted to reduce a range of traffic and environmental issues that have plagued modern cities. These issues include traffic congestion, traffic accidents and environmental pollution.

Despite the potential upsides to self-driving road vehicles there is still some uncertainty as to when they will arrive and whether they will bring about the full range of benefits their supporters purport [1]. Counter-intuitively, self-driving road vehicles could lead to an increase the number of vehicular trips. There are also concerns about whether these vehicles will make humans more sedentary.

Self-driving vehicles are not only restricted to road corridors. Drones are used extensively by the military and delivery services such as Amazon is experimenting with airborne delivery services direct to the home [2]. In Africa, essential medical drugs can be delivered by small autonomous planes that parachute urgent medical supplies [3].

Footpaths have also been used for autonomous vehicles. Domino's is trialling a pizza delivery vehicle in Australia and Amazon is testing parcel delivery services in the US [4].

These autonomous robots use a range of sophisticated sensory equipment to assist with navigation, including GPS, proximity sensors, image analysis, LiDAR and radar [5].

1.2 Less Active Kids

Parents today are very concerned about letting children walk to school [6]. Consequently, less than 20% of children walk or ride to school, whereas in the 1970's up to 80% of children walked to school. This is giving rise to so called lifestyle diseases such as obesity and diabetes in children that were once relatively rare [7]. Today, more than 25% of children are classified as obese. While junk food certainly plays a role, the inclusion of daily exercise is an important contributor to ameliorating this condition. One of the main reasons why children are not getting enough daily activity is because they are being chauffeured to and from school [8].

In Victoria, more that 70% of children are driven to school each day, even though more than 80% of children live within 3km of their school [9]. The high level of car trips is encouraged because of perceived risks stemming from traffic safety and stranger danger.

1.3 Walking School Bus

One alternative to the daily commute by car is for children to join a Walking School Bus (WSB). A WSB is managed by a responsible adult who walks with a group of children to school. The WSB travels along a predefined route and picks up children along the way at meeting points [9].

Even without a WSB driver, it is not uncommon for several children living nearby to walk together to school. Children today may also be equipped with mobile phones so that parents can talk to and supervise children remotely.

This paper explores the concept of a Robot Walking School Bus (Robot), as an extension to the traditional Walking School Bus. The project was developed as a collaboration between a local government (City of Whittlesea, Melbourne Australia) and students at a Maker Club (Mill Park Library, Melbourne, Australia).

2 Materials and Methods

2.1 Student Makers Club Evolution

In late 2014 the City of Whittlesea Waste and Recycling Team started experimenting with a small computer called the Raspberry Pi. The aim was to build low cost computer labs for schools using electronic waste and to teach students how to design and code electronic waste and sustainability related projects in schools and libraries [10].

The Raspberry Pi has its origins from researchers at Cambridge University, and was developed to be a cheap computer for children to hack and play with, to build up their coding skills.

The program won the Keep Australia Beautiful Victoria – Resource Recovery and Waste Management Award in 2015 and was a finalist in the Victorian Premier's Sustainability Awards (2015).

One of the outcomes of the program has been the establishment of the Mill Park Library Makers Club. The students at this Club were responsible for driving the development of the Robot Walking School Bus during the summer 2018/19 school term break.

2.2 Robot hardware and design elements

The chassis of the robot is the Wild Thumper 6WD robot (Dagu) which is capable of carrying a 5kg weight at 7km/hr (Figure 1). The walking speed for children typically ranges from 3 to 5km/hr depending on age and fitness. The chassis motors were controlled by a TReX Dual Motor speed controller (Pololu).

Figure 1: Close-up of Robot Walking School Bus on a footpath with a painted yellow line.

The microcontroller (electronic brain) used to control the robot was a Particle electron 3G microcontroller (Particle).

The Robot uses a digital camera to follow a painted yellow line on the footpath. Line sensing image analysis was provided by the OpenMV version M7 digital camera (Sparkfun).

While the Robot is designed to operate in autonomous line following mode, it can also be manually steered by students to get around obstacles. BBC micro:bits (BBC) using Bluetooth wireless were used to communicate with the Robot. The BBC micro:bit uses an accelerometer to register left and right turns to steer the robot. Manual and autonomous modes were selected using buttons on the BBC micro:bit.

To make the robot more endearing, sounds were added to provide cues to navigation, other sensory interactions, and general robot sounds. The effect is similar to the audio cues associated with George Lucas' R2D2. An Arduino microcontroller with an MP3 player shield was used to play sounds.

2.3 Footpath modification

A trial footpath was modified by painting a 25mm wide, unbroken yellow line in the middle of the footpath. The colour of the line can be either yellow or white and must provide sufficient visual contrast to the concrete footpath so that the computer vision algorithms can track the edges of the line. For a full-scale trial the painted line will be one-kilometre long. Decals stencilled on the footpath will be used to provide community education.

3 Results and Discussion

3.1 Robot Walking School Bus Concept Development

A Robot Walking School Bus (Robot) is an extension of a conventional Walking School Bus. The main change is the addition of a Robot to either accompany a Walking School Bus driver, or for the Robot to work exclusively with a group of responsible children, as shown in Figure 2.

Figure 2: Robot Walking School Bus.

The key design elements for the Robot Walking School Bus, as identified by the students are:

1. Children almost universally enjoy playing with robots [11], and walking to school with a robot therefore makes this mode of transport more appealing.
2. The Robot relies on a painted line of the footpath. Line following algorithms are relatively simple for computer vision systems, so this technology is easy for students to implement.
3. The students will be responsible for building and programming the Robot. This adds another layer of interest for students and encourages more student engagement in STEM and STEAM related subjects [12]. Students feel more empowered by this technology solution.
4. Using the Robot to walk to school addresses many health and environmental issues facing young people today, including obesity and diabetes [7].
5. There is significant interest in the future development of autonomous vehicles [13]. This application provides a relatively easy entry for students into this field.
6. By using Robots on footpaths to walk to school, other expanded local transport uses may be found. Examples include facilitating walking groups or running errands for seniors, and opportunities for traffic calming and place making.

3.2 Line Following Algorithm and Design Implications

One of the simplest algorithms used to guide robots are line-following algorithms. When robotics is taught in schools, it is very easy to program a robot to follow a line using simple sensors attached to robots.

China, has provided a real-life demonstration of a public train that follows painted lines on conventional roads showing that this technology is viable at full scale [14]. And while it is possible for robots to navigate footpaths without line markings, the navigational algorithms and hardware are more difficult for entry level students to understand.

By painting a line on the footpath and educating the local community about the Robot project there may be other unexpected community benefits. This may include attracting more pedestrian traffic to the marked section to footpath, taming traffic running parallel to the path, and helping to make residents more mindful of the presence of pedestrian traffic.

3.2 Robots and Students

School students always seem fascinated with building and programming robots. This partly explains why robot platforms are so dominant as learning tools when teaching students coding and STEM skills [15]. Popular robots in schools include Neo®, mBot®, Sphero®, Ozobot® and Lego Mindstorms®, to name a few. RoboGals, founded in 2008, was one of the first robot centric school programs tapping into this natural enthusiasm for robot construction [16].

While engaging for students, these robots typically have applications that are limited to the confines of the classroom. More adventurous education programs allow for robots to be taken into space, such as the SPERES program where students must program the robot to navigate in zero gravity on the International Space Station [17]. However, these programs are available to only a small number of students, are expensive and require more advanced programming skills.

Robot Battle competitions are also popular, and while they appeal to more students they do not instil the set of skills, ethics or morals we would like to see emulated in either robots or society [18].

The Robot Walking School Bus offers a practical and highly valued application for most schools and students for these key reasons:

1. Students have access to a real-world robot that delivers practical health, safety and learning outcomes.
2. The availability and cost of the technology is within reach of most schools (US$1,000)
3. The technology is open source and non-proprietary.
4. The design of the electronics and the software is teachable to school students ranging in ages from 10 and up.

3.3 Solving Wicked Problems

Many of the more enduring problems today are classed as “wicked” problems [19]. Traffic congestion, obesity, waste, social inequity and climate change are just some of the wicked problems our cities must confront.

Although the original concept for the Robot project focused on walking to school, the students found ways to make connections to other societal issues to strengthen their proposal.

The full range of benefits include:

1. Students walking to school will reduce traffic congestion, especially traffic around schools.
2. Less reliance on cars will reduce greenhouse gas emissions. The robot should incentivise other students to walk to school using the same method.
3. Walking to school will increase the amount of time students spend exercising outdoors.
4. The Robot has compartments that are designed to carry organic waste from student’s homes to school for composting. Less organic waste in landfill reduces greenhouse gas emissions. Students will also collect street litter to help keep local water ways free from stormwater pollution. Schools can be used as collection points for other diverse waste items such as electronic-waste.
5. More neighbourhood foot traffic will help to enhance a sense of community [20]. More foot traffic is also associated with traffic calming.
6. Skilling up students to be makers and exposing them to STEM and STEAM concepts will better prepare students for a technological future.
7. Walking to school should favour both girls and boys and contribute to other outcomes favouring improved social equity.

3.4 Students as Project Leaders

One key point of different with this project is the high level of student participation. Children in school are increasingly taught skills such as inquiry-based learning and how to collaborate as multi-discipline teams [21]. They may also be able to think around entrenched world models and existing social norms [22].

As the students have designed this project from the outset using inquiry-based learning, it gives them greater autonomy over the management, rollout, marketing and intellectual property.

3.5 Walking to School

Surveys conducted in the City of Whittlesea examining the travel habits of local students shows that 11% of primary school students walk to school (2017 Household Survey). VicHealth data indicates that 70% of children are driven to school, and yet 80% live within 3km of their school. By comparison, in other countries such as Japan, more than 80% of students walk, ride or take public transport to school [23].

The Walking School Bus is an initiative that aims to encourage more students to walk to school. The benefits include:

- Less traffic congestion around schools.
- Demonstration of sustainable transport.
- Encourages more community engagement.
- Improves safety and security in the street.

But there are significant challenges in establishing and maintaining a Walking School Bus (Bus) Program:

- Adult supervision is required.
- The outcome is often singular and isolated objective, and misses out on other community engagement opportunities.
- The program appeals more to younger children (prep to year 4)
- To date, the program has not made significant inroads into increasing the number of children walking to school.

Adding a Robot is expected to help address many of these issues. Although initial trials of the Robot will include adult supervision, the Robot and other on-board support equipment will guide the students safely to school without an adult being physically present.

The prospect of walking to school with a Robot is likely to appeal to a broader age group of students, especially if students are involved in making the Robot and planning the route. Our target is to increase student participation by 5% in the pilot school.

3.6 Robots and their Potential Role in Waste Management

The amount of electronic-waste being generated is growing logarithmically around the world [24]. This is driven by marketing, fast evolving technology and early obsolescence.

The students who participated in this trial are more mindful of waste because they have been using small Raspberry Pi computers built using old monitors, keyboards and mice donated by a local university. So, at conception, several waste management strategies were incorporated into this project.

Since the Robot was travelling to school, the students added a carry-compartment for organic waste, such as kitchen scraps. The aim is to take vegetable waste to school every day for composting. Once organic waste is composted it can be added to a fruit tree orchard at the school. Produce from the orchard can also be re-distributed back to the student community using the Robot. Composting at school has many advantages [25]. Schools can incorporate composting into sustainability teaching modules and composting reduces greenhouse gas emissions derived from the anaerobic decomposition of organic matter in landfills.

Students noticed along their route that there were often significant amounts of street litter. They added two additional compartments to the Robot, one for litter and one for recycling. They also added hand operated pickers to the robot (which look like robot hands) so that they could safely pick up litter along the way to school.

Very early in the development of the Robot, students made a connection between street litter and the health of marine life. There is significant concern among scientists that we are polluting the oceans and killing aquatic wildlife [26]. Street litter can easily wash away into local waterways and into the ocean causing the death of marine wildlife, as shown in Figure 3. The collection of street litter is seen by the students as an important daily function of the Robot.

Figure 3: Plastic found in the stomach of a deceased marine bird (CSIRO).

The ABC program “The War on Waste” hosted by Craig Reucassal has been widely promoted in Australian schools. In April 2019, the National Gallery of Victoria hosted the Victorian Design Challenge with a focus on waste. The Mill Park Library Makers Club students entered the competition with their Robot Walking School

Bus and won first prize in the Secondary and Primary School division of the competition [27].

3.7 The Maker Movement

The Maker Movement emphasises "learning-through-doing in a social environment". While it has always existed in some form, it has experienced a re-emergence in recent years due to the availability of low cost technology, construction equipment, delivery services and the availability of instructive resources on the internet.

Figure 4: Students from the Mill Park Library Makers Club with paper model of urban landscape.

The students collectively spent more than 400 hours building prototypes of both the Robot Walking School Bus and the urban landscape (see Figure 4). The first line following robot was a Zumo robot (Pololu). Houses, trees and water features were made using coloured art paper. The model provided the foundation for full scale trials of the Robot. All prototyping tools were designed to be reusable or recyclable.

3.8 Robot Walking School Bus and Place Making

Normally footpaths are designed and built by government agencies with minimal community engagement. David Engwicht, the creator of the "Walking School Bus" argues in his book "Reclaiming our Cities and Towns" that citizens need to be more involved in the evolution of built assets to help facilitate higher level community outcomes such as traffic calming and place making [20].

In addition to walking to school and processing waste, the increase foot traffic along the school route may also calm traffic, because of observed effects that foot traffic density may have on vehicular traffic speeds.

In the case of the Robot Walking School Bus, the painted yellow line and educational decals on the footpath could help concentrate local foot traffic. This backbone would then support a range of other community engagement opportunities such as local tree plantings and street art. The eventual aim is to give the community a sense of rootedness and connection.

3 Conclusions and recommendations

In Melbourne Australia most students travel to school by car. Being driven to school reduces the amount of exercise students receive and contributes to traffic congestion and greenhouse gas emissions.

A Robot Walking School Bus may encourage more students to walk to school by making this form of transport more attractive and safe for students. The Robot also incorporates design features that help students collect street litter and compost organic waste.

A student led approach to problem solving has broadened the benefits of using the Robot to help reduce street litter, protect waterways and marine animals, compost organic waste and activate urban spaces.

Acknowledgements

The Makers Club would like to thank YellowFin in Melbourne for their generous donation of laptop computers, CSIRO in Hobart for sharing their photos of birds affected by plastic waste and La Trobe University for donating old computer hardware.

References

1. B. Johnson and M. Rowland, 2018, "Automated and Zero Emission Vehicles, Transport Engineering Advice", *Infrastructure Victoria*. Accessed September 2018.

2. A. Miah, 2016, "Amazon delivery drones are just the first step to a highway in the sky", *The Conversation,* 27 July 2016. Accessed September 2018.

3. B. Mendelow, 2015, "How drones can improve healthcare delivery in developing countries", *The Conversation*, 6 November 2015. Accessed May 2018.

4. K. Letheren, 2017, "Experiments in robotics could help Amazon beat Australia's slow

delivery problem", *The Conversation*, 23 November 2017. Accessed November 2017.

5. Google, 2018, "Waymo 360° Experience: A fully self-driving journey", *YouTube,* 28 February 2018, https://youtu.be/B8R148hFxPw. Accessed September 2018.
6. J. Garrard, 2011, "Why aren't more kids cycling to school", *The Conversation*, 17 October 2011. Accessed May 2018.
7. A.R. Demaio, 2019, "More than one in four Aussie kids are overweight or obese: we're failing them, and we need a plan", *The Conversation*, 22 March 2019. Accessed March 2019.
8. H, Gilbert, A, Allan, C. Whitzman and J. Pieters, 2018, "Our chauffeured children are a problem we can't ignore", *ABC News*, 18 November 2018, www.abc.net.au/news/2018-11-18/car-era-and-children/10504960. Accessed November 2018.
9. VicHealth, "The Walking School Bus Program (now Walk to School) is a past VicHealth initiative that gave communities a way to get children to/from school again", *VicHealth*, 20 July 2015. www.vichealth.vic.gov.au/programs-and-projects/walking-school-bus. Accessed March 2019.
10. E. Lascaris, B, Harries, S. Chetwynd-Brown, K. Carlson and P. Ali, 2015, "Transforming electronic waste into social capital", *Unmaking Waste 2015 Conference Proceedings*, 22-24 May 2015, pp 435-442.
11. K. Sommer and M. Bodén, 2018, "Why R2D2 could be your child's teacher sooner than you think", *The Conversation*, 17 October 2018. Accessed October 2018.
12. B. Wade-Leeuwen, J. Vovers and M. Silk, 2018, "Explainer: what's the difference between STEM and STEAM?", *The Conversation*, 11 June 2018, Accessed December 2018.
13. M. Milford, 2018, "Driverless cars could create new jobs in a welcome boost to Australia's motor industry", *The Conversation*, 7 February 2018. Accessed September 2018.
14. P. Newman, 2018, "Why trackless trams are ready to replace light rail", *The Conversation*, 26 September 2018, Accessed September 2018.
15. L. Sterling, 2015, "Five reasons to teach robotics in schools", *The Conversation*, 27 October 2015, Accessed September 2018.
16. E. Davis, 2014, "Robot girls", *ABC Behind the News*, 13 May 2014, www.abc.net.au/btn/classroom/robot-girls/10528392. Accessed September 2018.
17. A. Park, 2016, "Zero robotics competition sees Sydney teens pilot robots aboard International Space Station", *ABC News*, 11 February 2016, www.abc.net.au/news/2016-02-11/sydney-teens-pilot-robots-aboard-the-international-space-station/7156872. Accessed September 2018.
18. J. Harland, 2017, "Artificial intelligence researchers must learn ethics", *The Conversation*, 29 August 2017. Accessed September 2018.
19. S. Manning and J. Reinecke, 2016, "We're failing to solve the world's 'wicked problems'. Here's a better approach", *The Conversation*, 3 October 2016. Accessed September 2018.
20. D. Engwicht, 1993, "Reclaiming our cities & towns. Better living with less traffic", *New Society Publishers*, Canada.
21. G. Kidman, 2019, "Explainer: what is inquiry-based learning and how does it help prepare children for the real world?", *The Conversation*, 1 May 2019. Accessed May 2019.
22. S.M. Cannon, 2019, "Climate strikes: Greta Thunberg calls for 'system change not climate change' – here's what that could look like", *The Conversation*, 15 March 2019. Accessed March 2019.
23. R. Moodie, 2005, "VicHealth submission to the parliament of Victoria, Road Safety Committee", *VicHealth*, 15 September 2005, www.parliament.vic.gov.au/images/stories/committees/rsc/prevention_pedestrian_accidents/Submissions/13-VicHealth.pdf. Accessed September 2018.
24. S. Herat, 2011, "E-waste: the high cost of high-tech", *The Conversation*, 12 December 2011. Accessed September 2018.
25. K. Block and B. Johnson, 2009, "Evaluation of the Stephanie Alexander Kitchen Garden Program", The University of Melbourne, http://mspgh.unimelb.edu.au/__data/assets/pdf_file/0010/2076733/SAKGP_Final_Evaluation.pdf. Accessed September 2018.
26. B.D. Hardesty and C. Wilcox, 2015, "Eight million tonnes of plastic are going into the ocean each year", *The Conversation*, 13 February 2015. Accessed September 2018.
27. C. McDowall, 2019, "Victorian Design Challenge 2019 – Winner announced at NGV", *The Culture Concept*, 21 March 2019, www.theculturalconcept.com/victorian-design-challenge-2019-winner-announced-at-ngv. Accessed April 2019.