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Towards Safer Routes: Exploring the Potential of Artificial Intelligence and Augmented Reality in Children's School Commuting Environment Design

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ABSTRACT

Augmented reality technology is characterised by its mobile, practical, multimodal, and data-driven trend. This paper presents a design framework that employs AI and augmented reality technologies to address an entire process of intelligent perception and design intervention for mitigating risks in children's school commuting environments. For intelligent perception section, 617 accident news texts were used for training purposes utilising natural language processing (NLP) and machine learning techniques. As a result, 6 influential characteristics related to children's school commuting environment (Time, road type, surrounding features, area functional type, user, age type and connection type). The prediction model holds 3 severity degrees and covers 6 types of incidents. For design intervention section, design strategies and techniques are defined based on various degrees. The prototype is designed using a mobile augmented reality device and a smart watch as design touchpoints.

Keywords: Augmented reality, Artificial intelligence, School commute, Environment design, Safety

INTRODUCTION

The spatial quality and environmental structure of urban residential areas play a crucial role in children's growth and development (Visser & Van Aalst, 2022). As an important part of urban transportation, children's school commuting environment has been wildly concerned (Ali et al., 2023). The school catchment policy devotes a lot of school-age children's activity time to commuting, which is vital for their growth (Kaseva et al., 2023).

School commute has clear destinations and travel chains, the spatial scale is concentrated on the residence, school and the path between them (Hoelscher et al., 2022). When school commuting is based on walking and promotes developmental dimensions including independence and sociality, it is defined as active school commute (Morris & Hardman, 1997; Tudorlocke et al., 2001). Active school commute is particularly effective against static lifestyles such as childhood obesity (Martin-Moraleda et al., 2022). It also allows children to stroll in the community life cycle and develop social communication and behaviour (Ding et al., 2023). Therefore, the

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pedestrian-oriented children's school commuting environment should be advocated and promoted.

However, urban transportation area is dangerous for children. Road traffic is the second leading cause of unintentional injury deaths among children (World Health Organization, 2023). In China, nearly 40,000 children die from unintentional injuries every year, drowning, traffic injuries and falls/-falls were the top three causes of injury (Chinese center for disease control and prevention, 2022). The safety of children is essential for every family, thus school commuting environment ought to be safe. SRTS programs create safe and convenient walking paths for children by improving the physical environment and facilities (Boarnet et al., 2005). The Dutch government has connected play spaces near schools to pavements and created Kindlint, a children's walking network (Liangwa, 2017). In Northeastern Ontario, a walking school bus pilot conducted practice (Scharoun Benson et al., 2020). Japan's urban planning laws already cover children's school commuting environment (Hino et al., 2021).

Regarding security, predicting is crucial. How can we predict hazard given existing hardware and environmental conditions? This demands intelligent environmental perception. This leads to 2 research questions:

RQ1: What affect the safety of children's school commuting environment?

RQ2: How to develop an intelligent children's school commuting environment security assessment model?

Once the risk occurrence mechanism is established, how can one quickly and accurately identify the present danger factor and notify the user? This article uses augmented reality (AR) to build a real-time monitoring and intervention system for children's school commuting environment. AR blends the physical and digital worlds into one experience (Vallino & Brown, 1998). It improves perceptions by integrating physical, geographical, traffic flow and user data to track environmental conditions continuously. This leads to the other research question:

RQ3: How can technologies represented by AI and AR empower the children's school commuting environment design?

This paper takes the environmental safety of children's school commuting as the starting point, explores how to combine AI and AR to forecasting, evaluating potential risks and implementing targeted interventions. Section 2 discusses the reasons why AR can enable school commuting environmental security. Section 3 introduces the overall framework of intelligent perception and design intervention. Section 4 covers data supply, processing, neural network machine learning model training and effect verification, and sensorium deployment via evaluation mechanism. Section 5 describes the systematic integration of the design intervention component with safety perception risk grading. Section 6 discusses innovations, limitations and future directions of improvement. Section 7 summarizes this paper.

MOBILE, PRACTICAL AND MULTIMODAL DATA-DRIVEN AR

AR technology is evaluated and its technical prospects, design aims, and application trends are discussed in this chapter. It demonstrates why augmented reality could enhance children's school commuting environment safety.

AR Technical Prospect: From Desktop to Mobile

AR technology and research can be defined by virtual-real content, real-time interaction, and 3D registration (Billinghurst et al., 2015). The typical application of desktop computing is zSpace (Aljumaiah & Kotb, 2021). Most desktop AR apps display 3D material using PCs and cameras. Mature desktop AR application devices are costly and limited in use because to their size and discomfort. Therefore, more applications transition from desktop computing to mobile computing (Farooq et al., 2002).

Mobile Augmented Reality (MAR) is a mobile device-based augmented reality interaction idea due to improved industrial production capacity and computer graphics and human-computer interaction technologies (Irshad et al., 2018). MAR allows real-time depiction of virtual material in free movement while maintaining an ideal spatial relationship between actual and virtual objects, which enhances the implantation of mobile augmented reality in our lifes (Henrysson, 2007). MAR developed in three phases.

The first stage, supported by smart glasses and helmets, uses autonomous AR hardware and software to perform spatial scanning, modelling and information processing. Modern HMDs allow toggling between virtual and reality (Pointecker et al., 2022). Microsoft HoloLens, Meta 2, and Google Glass are examples.

The second phase provides a MAR application combining AR software with desktops and smartphones. Integrated technologies such as efficient object tracking, fast processing, display and sensor, digital image recognition, computer vision tracking and registration are widely used (Reitmayr & Drummond, 2006; Feng Zhou et al., 2008). Interaction technologies such as browser-oriented interaction, analog video transmission and context-based interaction are also indispensable (Hürst & Van Wezel, 2013). After installing AR application software on their personal devices, users can apply the camera to scan and register to overlay virtual items in the actual world. Personal mobile smart devices make augmented reality more accessible.

Figure 1: Rabbit R1. (Source: Rabbit R1.)

The third phase of AR applications involves using AR as a bigger base layer to connect universal information functions. Meta-universe has spurred the development of virtual-application technology. New AR devices like the Rabbit R1 (see Figure 1) have sparked thinking about the next generation of personal computing platforms (Rabbit Technologies, 2024).

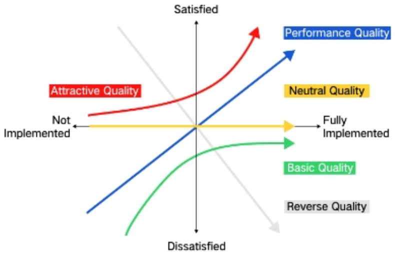


Figure 2: KANO model (Kano, 1984).

There is a progressive relationship between these 3 stages. The first stage completes the transition from AR technology to AR products, the second expands and promotes AR technology. The third indicates that MAR will become more important and widespread.

AR Design Goals: From Immersion to Practicality

AR has often been described to enhance user perception (Lindeman & Noma, 2007). It enhances user perception by displaying visuals, text, audio and video in real and virtual dimensions, creating an immersive experience (Bekele, 2021). AR fosters social connection through immersive personalised experiences, hence researches have examined immersion indicators in AR applications (Hofman et al., 2022; Kim et al., 2023). AR has proven to be valuable in improving *attractive quality* like immersion by encouraging user input through immersive encounters (Lee et al., 2022). If we back cast depending on user demand in the KANO model (Figure 2), may future AR enhance *basic quality* such as live security (Kano, 1984)?

It is limiting to regard augmented reality as just a display and interactive medium. AR differs from computers and mobile phones because it can capture actual space in real time, produce virtual space and content, and increase virtual-real merging. mobile devices will make Personal data gathering, analysis, and engagement more possible. Thus, future MAR should cover social functions, besides entertaining interaction, experiential immersion and aesthetic presentation.

AR Interaction: From Visualization to Multimodal and Data-Driven

Initially, AR was used to improve information visualisation, proving its effective appeal (Azuma et al., 2001). Information is connected to actual objects to improve visual perception (Sereno et al., 2020). This is a relatively simple visual superposition. Later study focused on AR's lightweight properties and how it may replace physical things. REVEL allows participants to feel virtual tactile textures when they touch real physical markers (Bau & Poupyrev, 2012). Two-way AR motion games let users feel the simulated applied force of the hit (Lindeman et al., 2012). AR reduces the need for real-world equipment to conserve resources and cost.

Multimodal AR, which integrates with reality, has emerged with spatial computing technologies. A virtual spider can respond to the real environment by blocking, accompanying and crossing (Corbett-Davies et al., 2012).

Chinese Academician Wu Zhiqiang's team has carried out city-scale AR applications (Liang et al., 2023). AR may engage all our senses with non-visual virtual and actual inputs. Thus, multimodal AR applications emerged.

Figure 3: Different stages of AR application function. (Source: the author.)

Lately, AR has expanded beyond the physical item, breaking through human perception of the actual world to assist people get abstract material like information flow and data more effectively and intuitively. ARToolKit tracking, point cloud identification and other three-dimensional spatial data acquisition methods reduce the threshold of virtual space reconstruction (Khan et al., 2018). Information simulation-based AR lets users see facts under the surface since technology can detect and react to real-world properties that humans cannot. MAR will be applied to perceive space, comprehend society, and touch information in addition to content presentation.

AR for mobility, practicality, and multimodality is vital while the fundamental and prospective innovation lies in data (see Figure 3). Smart city security relies on scientific traffic management systems based on urban sensors (Wang et al., 2023). This paper aims to improve the safety of children's school commuting environment via AR by applying urban physical and information data.

Design Framework Centred on AR

With AR technology supports, this paper forms a framework for children's school commuting environmental safety design, including *intelligent perception chain* and *design intervention chain* (see Figure 4).

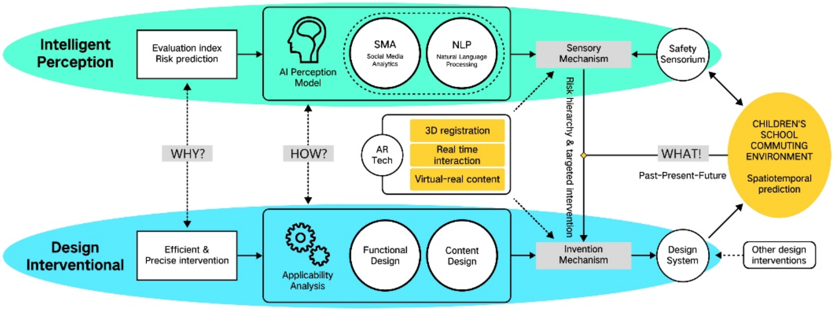


Figure 4: Framework of perception and intervention for children's school commuting environment. (Source: the author.)

INTELLIGENT PERCEPTION OF CHILDREN'S SCHOOL COMMUTING ENVIRONMENT

In this section, artificial intelligence and machine learning algorithms are used to analyse urban safety incident news texts. Urban safety influencing factors are summarise, risk assessment models are trained.

Data Crawling and Sorting

We analysed recent news to understand accidental injury. News data is clear and succinct, making it easier to analyse accident causes and consequences. Most news reports include accident monitoring, scene images, and other useful information to assist researchers comprehend the scenario.

Table 1. Basic data. (Source: the author.)

Source	Type	Raw data	Valid data
Sina Weibo	social media	127	107
safehoo.com	safe management website	284	252
toutiao.com	news portal	175	161
chinanews.com.cn	news portal	144	97

Python were used to extract information from different types of news websites. A total of 730 raw data were crawled. Due to each platform's core data formats and settings, some data is obsolete, duplicate, or irrelevant. This paper manually screened and unified 617 valid data.

Data Processing and Calibration

The paper organised the dispersed and imbalanced data using natural language recognition (NLP) and manual calibration, then processes the news text into the dataset. Factors (see Table 2) were explained by the logical of *when* (X_1)*-where* (X_2, X_3, X_4)*-who* (X_5, X_6) and 2 outputs (Y_1, Y_2).

Sensory Mechanism Model Training and Verification

This paper used machine learning models to predict the relationship between variables. The pandas and TensorFlow libraries were employed. After scanning training data, input and output variables were split and a neural network model with two hidden layers and a ReLU-activated output layer is trained. The mean square error loss function and Adam optimizer were used. 10 epochs were trained. 10 new accidents were collected for verification. The model performance was preliminarily evaluated by comparison (see Table 3).

Figure 5 shows the output and predicted output values to illustrate the discrepancy between model predictions and actual results. The average prediction deviation of the model for the comprehensive accident occurrence type is 0.97, but the average prediction deviation for mechanical injury (Y_1=5) is only 0.5. The average difference degree of Y_2 is 0.45. It may attribute this to the abundance of news accounts detailing incidents involving mechanical injuries seen in the original data set.

Table 2. Risk factors affecting children's school commuting environment. (Source: the author.)

Subject & Serial			Subject terms
X_1	Time	2	Daytime (7:00-19:00)
		1	Night (19:00-7:00 the next day)
X_2	Road type	3	Highways, traffic hubs, three-fork intersections, parking lots and other vehicle gathering places
		2	Special or non-standard roads such as national roads, mountain roads, village roads, bridge
		1	Standard urban street
		0	Not urban road accidents
X_3	Prominent features of surrounding area	4	Crowded places such as downtown, urban center area, important business districts
		3	Water bodies such as swimming pools, rivers, ponds and surrounding areas
		2	Site with height difference such as roof, hillside, high wall, fence or there are deep pits
		1	Isolated or enclosed spaces
		0	Not mentioned
X_4	Mainly area functional types	5	Comprehensive function area
		4	Industrial functional areas such as chemical factory
		3	Commercial function area
		2	Green area
		1	Residential community and campus area
		0	Not mentioned
X_5	Age type of victim	4	Adult (over 18 years old)
		3	Youth (13-17 years old)
		2	Children (7-12 years old)
		1	Infant (0-6 years old)
		0	Multiple ages included
X_6	Connection type	1	Accompanied or supervised
		0	Unaccompanied or unsupervised
Y_1	Accident type	6	Drop, downfall
		5	Mechanical injuries such as collisions, blows, car accidents
		4	Drowning, falling into the water, collapse, suffocate
		3	Electric shock
		2	Scald
		1	Biochemical damage such as poisoning, insect bites
Y_2	Accident severity	3	Cause death
		2	No deaths, but injuries
		1	No deaths or injuries were reported

It performed well on training data and made good validation data predictions. This illustrates that this model can capture the inner relationship, laying the groundwork for safety sensorium in the following section.

Safety Sensorium

In this chapter, a safety sensorium is organized. Low-precision urban area data will be provided using GIS and POI. Point cloud scanning and element identification will convert real objects into input data by providing high-precision and real-time information on the current condition of children's school commute environment. User age will be pre-set. User response within the community will be used to gauge the exist of connection.

Table 3. Predict data. (Source: the author.)

	X_1	X_2	X_3	X_4	X_5	X_6	Y_1	Y_2	Predicted_Y_1	Predicted_Y_2
1	2	1	4	1	2	0	2	2	4.99	2.97
2	2	0	2	1	1	1	6	2	4.49	2.50
3	2	3	1	5	1	0	5	3	5.17	3.16
4	2	3	0	3	1	0	5	3	4.63	2.80
5	2	1	4	3	1	1	5	3	5.33	3.14
6	2	0	3	2	2	1	4	3	4.89	2.89
7	2	1	0	1	2	1	5	3	4.05	2.56
8	2	1	1	1	1	0	4	3	3.69	2.12
9	2	0	1	3	2	1	5	2	4.29	2.64
10	2	0	2	1	1	1	6	2	4.49	2.50

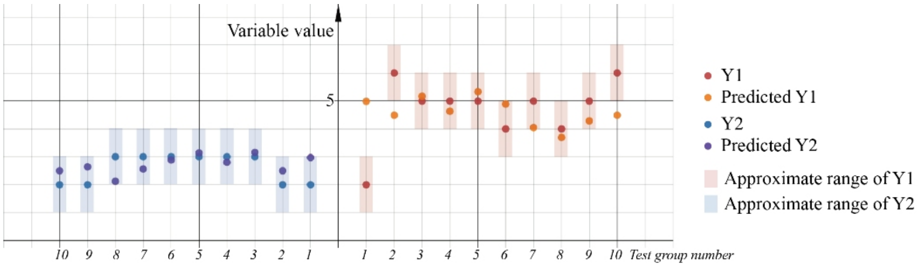


Figure 5: Visualization of the test group compared to the actual Y value. (Source: the author.)

Table 4. Security level define. (Source: the author.)

	Security level	Annotation
0.00<Predicted_Y_2<1.50	I	Very low risk, less likely to cause harm
1.50≤Predicted_Y_2<2.50	II	May cause injury, need attention
1.50≤Predicted_Y_2	III	May cause life threatening injury

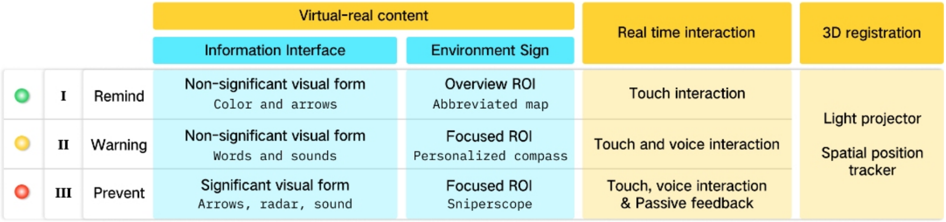
Table 5. The correspondence between safety sensorium and technology. (Source: the author.)

	City sensor	Personal mobile devices (AR-enabled)	Other sources
X_1			Time set
X_2	GIS data	GPS data	
X_3		3D Point cloud scanning	
X_4	POI data	Street view features identification	
X_5		Pre-set user information	
X_6		Bluetooth search	

This processing connects the real school commute environment and users with the perception chain, making it simple for both professional or non-professional stakeholders, like designers, teachers and parents, to assess the road safety of children's school commutes and define potential hazards.

DESIGN INTERVENTION OF CHILDREN'S SCHOOL COMMUTING ENVIRONMENT

Aiming at security, efficient implementation and information customisation are essential. Efficient implementation requires respond rapidly in an emergency. Information customisation demands easy-to-understand security interventions to treat and avoid hazards for varied risk and site.



			Virtual-real content		Real time interaction	3D registration
			Information Interface	Environment Sign		
🟢	I	Remind	Non-significant visual form `Color and arrows`	Overview ROI `Abbreviated map`	Touch interaction	Light projector Spatial position tracker
🟡	II	Warning	Non-significant visual form `Words and sounds`	Focused ROI `Personalized compass`	Touch and voice interaction	
🔴	III	Prevent	Significant visual form `Arrows, radar, sound`	Focused ROI `Sniperscope`	Touch, voice interaction & Passive feedback	

Figure 6: Invention mechanism of severity, function and design strategy. (Source: the author.)

This chapter takes MAR applications and smart watches as design touchpoints for prototype. Three functions are defined. Level I correspond to the *Remind* function, which sends a message to remind the user to focus. Level II correspond to the *Warning* function, which contains light warnings and warnings of danger sources. Level III correspond to *Prevent*, which includes continuous audible and light warnings, as well as the activation of community alarm services. Then, the content design is determined according to the three definitions of AR (see Figure 6). The design content is classified in visual form and region of interest.

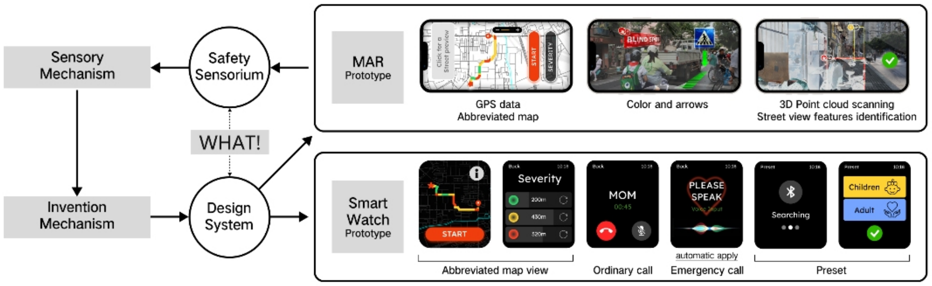


Figure 7: Prototyping and system operation structure. (Source: the author.)

Environment perception, real-time input, and community mutual perception are used to create the prototype (see Figure 7). This system can enhance the safety of children's school commute and offer an innovative and intelligent approach to urban planning and safety management.

DISCUSSION

This paper establishes an evaluable and perceptive intelligence model for the safety evaluation of children's school commuting environment. Using mobile data and AR technology, a system of hardware wearables and smart peer school commuting apps is formed.

However, this paper only provides limited implementation approaches, and other design methods and innovations may merit debate. The risk factors in this research can be subdivided. School commuting behaviour is also affected by weather and other variables (Antoniadis et al., 2020). Along with road accidents, violent and gun-related crimes are also important threats (Gobaud et al., 2023). Future accident data additions may make the prediction model more ubiquitous, model verification accuracy can be improved with frequent verification and many average values.

CONCLUSION

This paper proposed a design framework that prioritises data and intelligent algorithms above mere spatial regeneration, to investigate the development of a smart, safe and sustainable school commuting environment. It forms effective evaluation indicators, which can form intelligent perception of urban environment and human flow behavior with the help of urban sensors, and carry out cyclic and dynamic evaluation and prediction of children's school commuting environments. Augmented reality and artificial intelligence are applied to create a design system that encompasses environment perception, real-time feedback and community mutual perception. It provides a useful experience for creating a safer commuting environment for children's schools, also proposed an approach for future city perception and interaction.

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