Development of a Creative Styling for Automated Guided Vehicle

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***Abstract*—This study proposes an innovative design for the automobile body of an automated guided vehicle. Its main feature is the use of a cartoon panda bear image for the vehicle's appearance. The innovative design incorporates the likeness of a panda's body, i.e. its roundness and black and white color contrast. There are two ears on the vehicle panel, creating an eye-catching image. A panda face with a cutesy appeal is on the front section of the vehicle. Two headlights are installed in the eye sockets. When the vehicle moves, it has brightly lit eyes that bring a cheerful energy to a factory. Overall, the innovative design developed in this study turns the unexceptional look of an AGV into that of an appealing panda bear, thus improving the AGV's presentation and making it unique. The design is greatly appealing and its appearance will create a distinctive visual effect.**

Keywords—automated guided vehicle; panda; shell design; LED panel

I. INTRODUCTION

An automated guided vehicle (AVG) loads goods through automatic or manual means, and then automatically moves or tows a carrier to the destination according to preset paths.This is an industrial vehicle that uses automated or manual means to load and unload goods. AGV paths are normally created using underfloor cables or reflective paint on the floor. A sensor installed on the vehicle then guides it along theses pathways formed using cables or paint. Japan's JIS D 6801 defines the AGV as a battery-powered and automated operating industrial vehicle [1]. The AGV is a wheeled mobile robot (WMR). In other words, it is an unmanned transport vehicle.

The AGV follows requirements regarding the automation, flexibility, and optimization of material transportation operations and involves the use of an AGV system, an automated loading and unloading system, a communication system, a safety system, and a management system, among which the AGV system [2] is of the greatest importance. AGVs have been used in areas such as warehousing, manufacturing (automobile factories, pharmaceutics, food, chemistry, etc.), post offices, libraries, ports, airports, etc. With the development of electronic and microprocessor technologies, AGVs have become more intelligent while AGV pathfinding has become increasingly simplified, which has resulted in the wider application of AGVs [3-10]. Different guiding methods have been developed, improving the performance of AGVs and making them applicable to more complex industrial environments. This has resulted in their application scope being expanded.

The increasing number of AGV manufacturers reflect the growing market demand for AGVs. By the end of the 1970s, only six manufacturers in the US produced AGVs, and there were only three AGV models. With growing concern about product standardization, the number of manufacturers producing AGVs worldwide had increased to 40 by 1990, while the number of AGV models had increased to 15 [11]. Developments in science and technology will continue to drive AGV innovation. More and more AGVs are being used, which has increased investments into AGV research and development. As stated in one industrial report [12], the modern AGV manufacturing industry in the US is in its growth phase. From 2012 to 2021, the average annual growth rate of the industrial value added (IVA) used to measure the industry's contribution to the economy of the US is projected to be 7.2%. In the same period, the average annual growth rate of the US's gross domestic product (GDP) is projected to be 2.2%. The fact that the IVA growth rate is greater than that of the GDP shows that AGV industry has great developmental prospects over the next five years.

In recent years, Taiwan's industries have been actively introducing automated systems, and the AGV serves as a bridge connecting them. AGVs outperform manual transportation in terms of safety, cost, production planning, and inventory control, thus solving problems such as a lack of manpower, delivery errors, lack of materials, etc. Therefore, the AGV is necessary in automated production processes if one seeks to gain a competitive advantage in the manufacturing industry.

II. PURPOSE OF RESEARCH

The AGV is an important component in the automated material handling ecosystems found in

factories and warehouses. Guidance technologies [13, 14] determine the flexibility of the logistics system formed by AGVs. Among modern guiding technologies, the most developed and reliable is electromagnetic induction, which is produced using embedded cables [15]. Wireless guiding technologies are expensive but have low operating costs due to simple and convenient path configuration and modification. Wired guiding technologies have stringent requirements regarding surface levelling and cleanliness. Path configuration and modification are complex components in electromagnetic induction technologies and their installation costs are high. Image recognition technologies for grid pattern [16-18] boast large data capacities and are characterized by simple and convenient path configuration and modification, oriented control flexibility, and high vehicle positioning accuracy, thus allowing them to potentially be used in a wide range of applications.

Most modern AGVs used in factories move via magnetic tracks and use lifting bars to tow shelving racks. Due to traffic control issues, as well as the fact that the intelligent and management aspects of the system have yet to be fully realized, there remains much space for improvement. In this study, AGVs currently used in factories were the targets for innovative remodeling, and software and hardware reconstruction were aimed at improving the practical performance of AGVs. This research and development plan includes short-term, mid-term, and long-term objectives. Each of these three phases is six-months long. With regard to short-term objectives, the authors aim to develop an innovative presentation that can adapt to different industries. This would transform the AGV from a moving machine into an "assistant" that can be integrated into the work environment.

With regard to mid-term objectives, the research team intends to change the existing control button and graphic display layout to a liquid crystal control panel, which will reduce the number of unnecessary buttons and improve appearance of the robot, and the panel will come with a protective cover. These additions will give the AGV a more modernized look. A real-time video chat function will be added to the AGV to facilitate human-machine interaction.

With regard to long-term objectives, this study aims to improve the magnetic track-based AGV operation model so that AGVs can plan operation paths and calculate the fastest routes via a digitalized grid coordinate system, which will wean them off their reliance on magnetic tracks. Moreover, the inter-school research and development team aims to improve on previous methods of towing the shelf racks and placing them on the machine platform. This study added retractor devices and gripping jaws to the AGV platform so that it could extend toward shelves during transportation operations and stabilize the rack by clamping on it. This would greatly improve material transportation safety.

This study describes the results of the first phase of the research plan, which is the development of an innovative presentation for AGVs. Due to the increased demand for AGVs in China in recent years, this study opted for the panda, an animal found only in China, as the theme of the vehicle's design in order to make innovative AGVs a touchstone in the market of China.

III. Methods and Materials

Scientific name of the panda: The Ailuropoda melanoleuca, or giant panda, is a large bear with a round head, short tail and distinctive white and black fur. The giant panda is a protected animal in China and also an endangered species. Its research value and cute image appeal to many people worldwide, particularly children. In 1961, when the World Wide Fund for Nature (WWF) was established, the giant panda was chosen as its symbol (Fig. 1). The giant panda has already become the symbol for endangered species protection. The panda is often considered a good luck symbol and mascot all around the world, and the panda craze has swept the globe numerous times. The giant panda has also become a fashion trend, with many brands launching their own panda-themed lineups.

Fig. 1. *WWF symbol.* [Source: http://www.wwfchina.org/]

The original AGV frame (Fig. 2) was manufactured from SS41 steel that did not undergo prior surface treatment and had a tensile strength of 41kgf/mm^2. The motor and front movable guided fixed pulley brackets were connected using S45C steel (tensile strength of 58kgf/mm^2) that had underwent surface treatment (using 0.05 mm thick plating layers). An aluminum alloy with a tensile strength of $>$30kgf/mm^2 was used for the battery rack and electric control mount.

For the design developed in this study, 3-mm thick aluminum alloy panels were used for the AVG shell to reduce its weight. The machine shell was manufactured through sheet metal bending, impact extrusion, and welding; the shell's dimensions are L630×W420×H230, as shown in Fig. 3.

After the vehicle shell was manufactured according to the design, black and white stoving varnish was used, as shown in Fig. 4. Golden colored varnish was used for the black stripes and some parts of the

vehicle body. The vehicle shell was locked together using sunk screws. Nickel screws were used due to cost considerations, and also since the use of aluminum alloy in the shell's production meant that the usual method of screw welding would not be feasible given the alloy's low melting point. Blind nuts were added for blockade purposes and white pasters were used to conceal the lock points.

Acrylic resin was used for the L-shaped battery cover in the AGV shell and galvanized iron hinges were used for its connection to the shell. The vehicle body was equipped with a baffle plate in order to prevent the acrylic resin from bending due to weight. Due to cost considerations, during the development period, 3D printing was used to manufacture the back and front paws, ears, eyes, nose, and tail that were then covered with stoving varnish. The completed, innovative AGV shell as illustrated in Fig. 5.

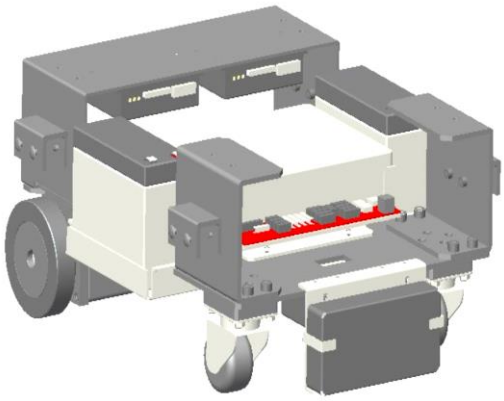

Fig. 2. *3D render of original AGV frame.*

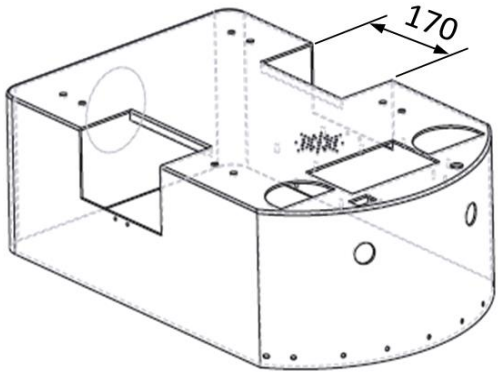

Fig. 3. *AGV shell design.*

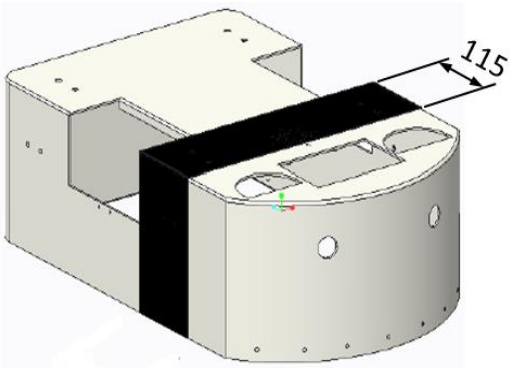

Fig. 4. *AGV shell stoving varnish.*

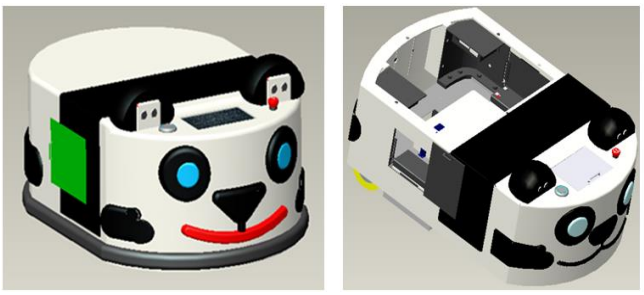

Fig. 5. *3D rendering of AGV shell.*

The vehicle control system that provides automated guidance to vehicles, i.e., the AGV control system, receives instructions from a host system and then conveys the guidance, path selection, drive, loading instructions to individual units. The existing AGV is equipped with management and navigation software. The management software system is used for traffic control and operational management and the navigation software is used for measuring and calculating positional and directional coordinates. The proposed plan retains the functions of the management and navigation software but replaces the currently used control buttons and graphic display with an LCD panel in order to improve the user-friendliness of the human-computer interface.

IV. Results and Discussion

The proposed plan focuses on reconstructing the AGVs currently used by partnering factories and improving their performance. The AGVs' reconstruction includes developing a panda-themed shell, changing the existing control panel into a sensor panel, and replacing light-emitting diode (LED) switch buttons with LED emergency stop buttons. The implementation of a sensor panel required the height of the vehicle shell to be adjusted, and the three bases of the internal shell foundation also underwent height adjustments. The vehicle's required load capacity was set to 100 kg. 12V/10A lead-acid batteries were used as the source of electric energy. A brushless motor was used as the driving power supply. The original AGV could be rotated 180°, which is used in catering, document delivery, and the transportation of light materials.

The completed AGV frame is illustrated in Fig. 6, the total weight of the AGV frame is about 29 kilograms. Due to the hardness of the material, the frame can bear heavier loads, i.e., the working load is 100 kilograms.

The main colors of the panda are black and white. Its ears, eyes, nose, shoulders and four paws are black and the rest of the body is white. The most distinctive feature of the panda is the black patches around the eyes. When a panda is in a snowy environment, the background blends with its white sections, leaving only black parts visible. On the contrary, in dense and dark bamboo forests, the black sections vanish, whereas the white sections are easily

spotted. This gives pandas an “imperfect” silhouette, thus reducing their risk of being attacked.

Fig. 6. *Photo of AGV frame.*

Theories of chromatics classify black and white as achromatic colors that differ only in terms of brightness. For scientists, white is a color, whereas black is not. For artists, black is a color, whereas white is not. The color psychology suggests that black symbolizes authority, elegance, a low profile, and creativity, and white symbolizes purity, sacrament, kindness, trust, and openness. The intense contrast between black and white reflects the feel and style of the developed product, particularly, its relation to “esthetics” and “design.” The use of black and white colors made the product eye-catching.

The AVG shell manufactured in this study has a curved streamlined design, the net weight of the AGV shell is 4 kilograms. Its cheerful and appealing presentation energizes the workplace. The black and white colors of the panda used in the AVG shell have a strong visual contrast, which serves a warning function and increases the safety of the work space. The innovative design of the completed AGV shell is illustrated in Fig. 7.

Fig. 7. *AGV shell’s innovative design.*

In the mid-term phase of the proposed plan, the functions of the original management and navigation software will still be retained, but the control buttons and graphic display will replaced by an LCD panel, as shown in Fig. 8. When the circuit board used by the partnering factories is switched on, the system automatically starts the AGV APP, followed by the start page, and then the main page and keyboard page shown in Fig. 8.

Fig. 8. *Photo of AGV LCD panel.*

The LCD panel is divided into three layers, as shown in Fig. 9. In the developed LCD sensor panel illustrated in Fig. 9, the first layer is the key frame that includes the functional diagram of the second layer frame, triple-grid electric energy display (full indicating that the battery is 24.5V), nine-level volume display, and card positioning diagram. The second layer includes the “Functions and Options” and “Time Settings” pages. The third layer includes the “Map Implementation”, “Test Mode”, “Map Reception Screen”, and “Control Mode, Patrol Mode, Editing Mode” pages.

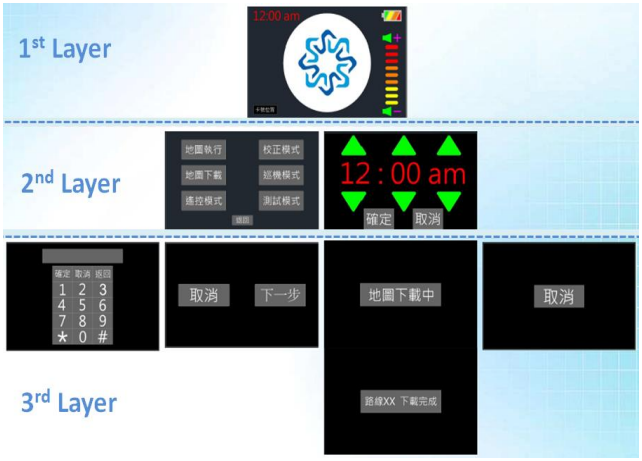

Fig. 9. *AGV LCD panel.*

V. CONCLUSSIONS

Many people have seen efficient warehouse robots handling numerous orders in Amazon’s logistics centers. Such AGVs exist not only in Amazon facilities but also in many factories in Taiwan and China. According to statistics provided by the International Federation of Robotics (IFR), the Chinese AGV market had grown to 28,000 units by 2014 and caught up with Japan. By 2015, the number increased to 34,000 vehicles, which was 3,000 more compared to Japan, thus raising China to first place. It is estimated that in 2017, China will become the country with the largest demand for industrial robots.

China is fast becoming the country with the highest number of robots. In 2015, China had more newly installed industrial robots than Japan. China, “the

world's factory," is already facing the issues of labor scarcity and growing labor costs, hence the trend toward the use of robots to form an advanced production base is an unavoidable one. Chinese manufacturing plays an important role in the world's manufacturing industry. However, it is still strongly associated with general-level manufacturing. The growing costs of labor, materials and energy, as well as difficulties in recruiting workers, are all practical issues that the Chinese manufacturing sector has to deal with. Under this backdrop, manufacturing automation and informatization, as well as industrial upgrading, have become the primary goals of the sector. The above shows that the demand for AGVs in China will increase in the coming years, which reflects China's AGV demand trend and the potential opportunities there.

The AGV external design proposed in this study has a panda theme. Panda features, such as black patches around the eyes and the contrasting white and black colors of a panda's fur, were incorporated into the design to create a cute-looking Panda AGV. Panda vehicles moving around the factory can create a positive vibe, thus increasing work efficiency.

The two universities that developed the proposed plan completed the Panda AGV through cooperation with various companies. The team plans to develop a number of innovative AGVs (e.g., panda, Taiwan blue magpie, etc.) for Taiwanese companies and to have factories and businesses operating its specially designed AGVs.

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REFERENCES

[1] Standard:JIS D6801:1994, "Glossary of terms relating to automatic guided vehicle systems," Jpn. Stand. Assoc., 2005.

[2] S. Berman, E. Schechtman, and Y. Edan, "Evaluation of automatic guided vehicle systems," Robot. Comput.-Integr. Manuf., vol. 25, no. 3, pp. 522-528, 2009.

[3] L. Schulze, M. Lucas, and A. Baumann, "Automated guided vehicle systems - Trends in technology and application," Proc. of IMECE2005, ASME Int. Mech. Eng. Congr. Expo., Florida, USA, 2005.

[4] L. Schulze and M. Lucas, "Logistics and automation state of the art and trends in Europe," Greater Chin. Supply Chain Logist. Forum Acad. Conf. 2005, 30 October 2005, Nanjing, China.

[5] L. Schulze and A. Wüllner, "The approach of automated guided vehicle systems," 2006 IEEE Int. Conf. on Serv. Oper. Logist. Inf., 21-23 June 2006, Shanghai, China.

[6] L.D. Zhao, L. Schulze, and X.L. Ma, "Application and development of AGVS in China," Logist. Technol., vol. 25, no. 12, pp. 27-30, 2006. (in Chinese)

[7] L. Schulze and L. Zhao, "Worldwide development and application of automated guided vehicle systems," Proc. of the Int. Conf. Greater Chin. Supply Chain Logist. Conf. 2006, pp. 130-137, 09-11 December 2006, Hong Kong, China.

[8] L.D. Zhao, L. Schulze, and X.L. Ma, "Impact of automation technology on logistics systems," Proc. of the Int. Conf. Greater Chin. Supply Chain Logist. Conf. 2006, pp. 629-634, 09-11.December 2006, Hong Kong, China.

[9] L. Schulze and L.D. Zhao, "Global development of automatic guided vehicle systems," Int. J. Servi. Inf., vol. 2, no.2, pp. 164-176, 2007.

[10] L. Schulze, S. Behling, and S. Buhrs, "Automated Guided Vehicle Systems: A driver for increased business performance," Proc. of the Int. Multi-Conf. Eng. Comput. Sci., vol II, 19-21 March 2008, Hong Kong, China.

[11] Wikipedia, "Automated guided vehicle," Available at: https://en.wikipedia.org/wiki/Automated_guided_vehicle, 29 September 2016.

[12] IBISWorld, "Automated guided vehicle manufacturing in the US: Market research report," Available at: http://www.ibisworld.com/, May 2016.

[13] J. Long and C.L. Zhang, "The summary of AGV guidance technology," Adv. Mater. Res., vol. 591-593, pp. 1625-1628, 2012.

[14] H. Martínez-Barberá and D. Herrero-Pérez, "Autonomous navigation of an automated guided vehicle in industrial environments," Robot. Comput.-Integr. Manuf., vol. 26, no. 4, pp. 296-311, 2010.

[15] Y.D. Zhan and Y. Luo, "Guided and detecting technology of intelligent robot AGV and new-style AGV," Proc. SPIE 4077, Int. Conf. on Sensor. Control Tech., p. 461, 9 May 2000.

[16] M. Bertozzi, A. Broggi, and M. Cellario, "Artificial vision in road vehicles," Proc. of the IEEE [C], vol. 90, no. 7, pp. 1258-1271, 2001.

[17] H.W. Chen and G.B. Yuan, "The recognition of regions based on map images," Comput. Eng. Sci., vol. 25, no. 1, pp. 33-49, 2003.

[18] C. Charde, M. Sheoran, G. Kolh, and A. Nandanwar, "Design and modelling of an autonomous automated guided vehicle with intelligent navigation control system," Int. J. Eng. Tech. Res., vol. 3, no. 3, 2015.