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LINE RECOGNITION SENSORS

Urgency of the research. *There is a need from industrial practice for developing of methods for linefollowing navigation of automated guided vehicle (AGV) for logistic task in factories without operators.*

Target setting. *Various types of navigation methods are used for vehicles.*

Actual scientific researches and issues analysis. *Navigation of this automated guided vehicle can be made through the color line on ground or through the inductive sensed cable located underground. Also magnetically guided method is used. Various types of optical markers can be also used. Nowadays this type of autonomous robot applications grows up, because there is a need from industry.*

Uninvestigated parts of general matters defining. *Next generation of automated guided vehicle is navigated via using laser scanners and they are also called LGV – Laser Guided Vehicle. This type is not covered in this paper.*

The research objective. *The main aim of paper is to design the sensing system for color line sensing. There are several problems in using of these types of sensors. Manufacturer notes that there is placed daylight filter, but first experiments shows sensitivity to daylight. This problem can occurs when vehicle goes to tunnel. Next problem is when vehicle moves uphill and downhill on a bridge.*

The statement of basic materials. *The color of sensor can be sensed with sensor - reflection optocoupler working in infrared light range. The optocoupler includes the infrared LED transmitter and infrared phototransistor, which senses the reflected light. Optocouplers are placed on bottom side of vehicle. Navigation line is black and other ground area is white. Optocoupler located over the navigation black line has no infrared reflection.*

Conclusions. *The selected sensor system has been adapted for line detection application. Also ramp problems have been solved. Sensors have been successfully installed on linefollower vehicle. Results shows visible difference between the voltage levels related to black and white color line. Future plans is to add camera vision system for automatic recognition of line before vehicle and continuously path planning. Vision systems are also frequently used for obstacle detection and mapping of environment and consequently for path planning.*

Keywords: *sensor, mobile vehicle, line, color.*

Fig.: 10. References: 17.

Introduction. Automated guided vehicle (AGV) is an industrial application of mobile vehicle for line-following. It means that AGV vehicle has task for transport any material in factory without operator access. Navigation of this vehicle can be made through the color line on ground or through the inductive sensed cable located underground. Also magnetically guided way is used. Various types of optical markers can be also used. Nowadays this type of autonomous vehicle applications grows up, because there is a need from industry. The applications are related to material or parts transport between operations places. The AGV saves the production costs in logistic process mainly in large mass product productions, because there is less human work. Automated production lines or warehouse can work fully continuously without any delay. Automotive production industry is also one of the possible applications of AGV vehicles. AGV can have a concept of more towed vehicles like wagon train. Also forklift stacker can be arranged into AGV system. The concept of AGV systems is older. It comes from fifty years of last centuries.

Fig. 1. Automated guided vehicle [1; 2]

Color line is one of the possible way of navigation, but there is a risk of dirties on line and fault detection of line. In case of using the underground wire, there is a frequency modulated method is used for navigation. Installation of cables needs many initial costs before installation and it is not so flexible when change of the road is needed [1-10].

Next generation of AGV is navigated via using laser scanners and they are also called LGV – Laser Guided Vehicle. Method of simultaneous localization and mapping (SLAM) is used for navigation. This method also allows using in environment with dynamically changed obstacle. SLAM algorithms need more powerful computation system and more sophisticated sensors. SLAM makes a topological map of environment and generates the estimate of next move direction [6, 7] through the using of statistical methods.

Next way of navigation is using of inertial navigation systems or inertial measurement unit (IMU), which includes accelerometers, gyroscopes and compasses. This method is more flexible but it is necessary take into account navigation errors which can occur.

There are several robotic competitions with linefollower category which is as analogy to automated guided vehicle navigated through the color line or underground wire. Our testing model uses the differentially driven two wheeled undercarriage with third castor wheel for stability. For better simulation of real conditions we have built the training road with obstacle, tunnel, bridge with up and down ramps, line junction and line interruption.

Designed vehicle (fig. 2) uses two DC motors with wheels directly placed on output shafts. Castor wheel is substituted with ball. The aim was to design lightest undercarriage. For this reason there is no frame and all parts are directly placed on printed circuits boards (PCB). Vehicle is controlled via using of microcontroller. Key parts of the vehicle are sensor for line detection. This vehicle is used primarily for educational purposes.

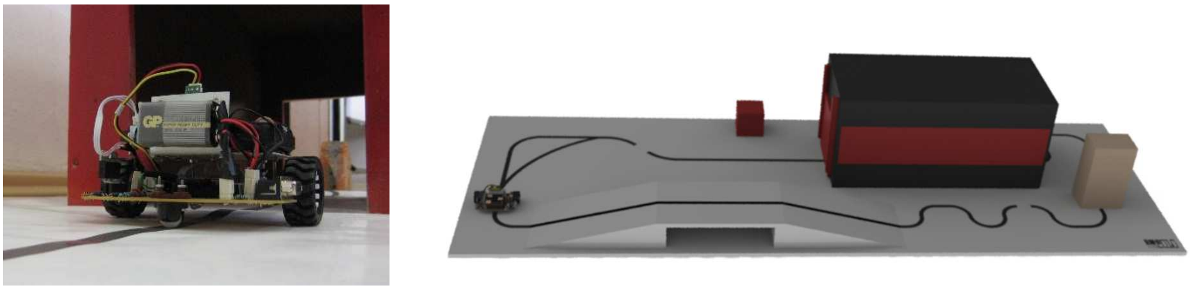

Fig. 2. The model of the linefollower vehicle

1. Color sensors. The color of sensor can be sensed with reflection optocoupler working in infrared light range. The optocoupler includes the infrared LED transmitter and infrared phototransistor which senses the reflected light. Optocouplers are placed on bottom side of vehicle (fig. 3). Navigation line is black and other ground area is white. Optocoupler located over the navigation black line has no infrared reflection (fig. 3).

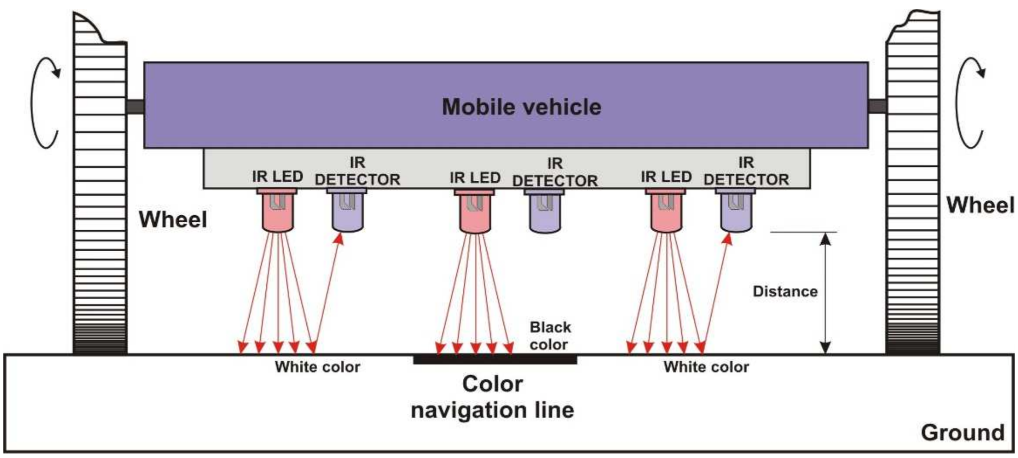

Fig. 3. Optocouplers on mobile vehicle for linefollowing

There are several problems in using of these types of sensors. Producer notes that there is placed daylight filter, but first experiments shows sensitivity to daylight. This problem can occurs when vehicle goes to tunnel. Next problem is when vehicle moves uphill and downhill on bridge. Bridge ramps cause the change of distance between the sensor and ground. These types of sensor are not primarily dedicated for this purpose. That is the reason, why there is no mention about linefollowing functionality in datasheets.

Experimental testing has been done with three selected type of sensors QRD1114, LTH209-1, CNY70 (fig. 4). All theses sensors are designed as reflective optocoupler sensor for detection of objects.

Fig. 4. Tested infrared optocouplers

All tested sensors have been placed on movable platform (fig. 5) with white reflective area. The distance has been adjusted in range from 0 to 20 mm for all sensors together with step 1 mm.

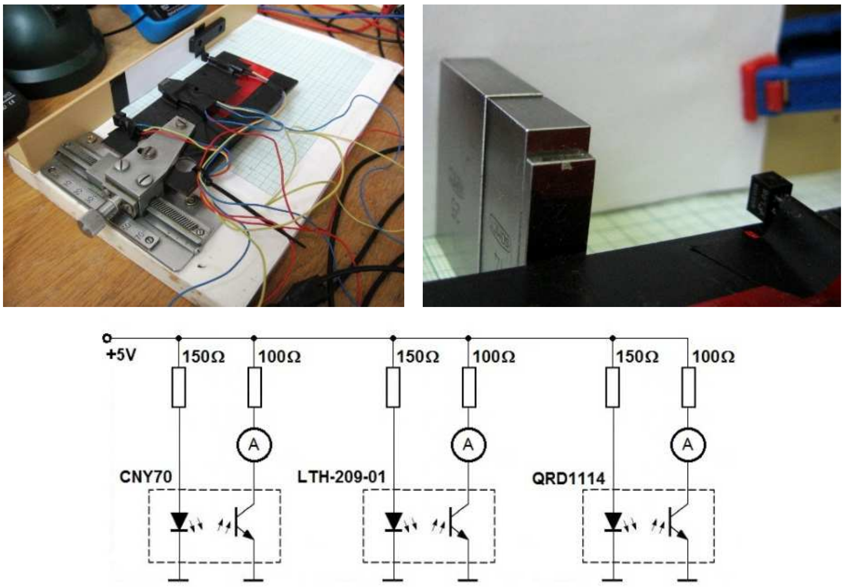

Fig. 5. Testing of various types of optocouplers

Figure 6 shows results of testing for all sensors. All sensors react to white reflective surface. The measured current depends on excitation of infrared LED diode. The circuit (fig. 5) used the same resistors before LED diodes and this resistor should be adjusted for every coupler LED. The maximum measured current shows the optimal distance of sensor during the detection white surface. Experiments shows that all tested sensors are suitable for line detection. QRD 1114 has been selected for next experiments.

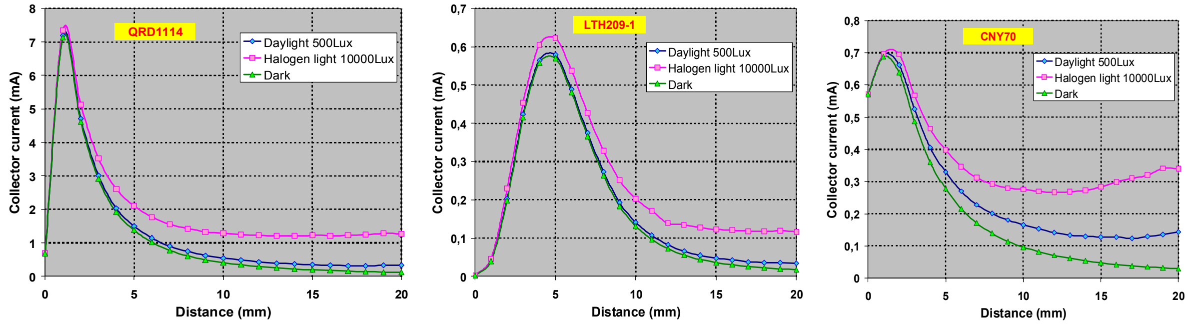

Fig. 6. Results of optocoupler sensors testing.

Next tested property was the difference between the black and white colors of reflective surface. Also next question was if the every piece of sensor has the same behavior. Two pieces of these sensors have been placed on the same movable platform (fig. 7). Figure 7 shows difference electrical current during the sensing black and white surface. There was a different behavior for tested pieces on black surface. The results show the optimal detection distance value 2 mm.

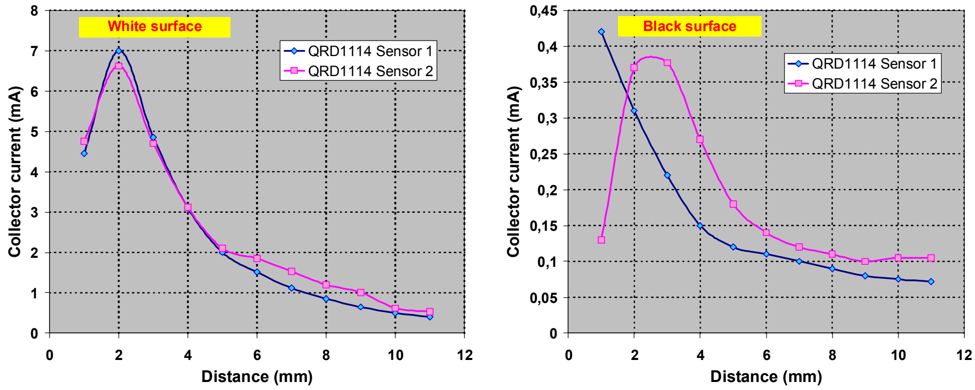

Fig. 7. Results of testing for two pieces of optocoupler

Vehicle has to go uphill and downhill on bridge ramps (fig. 8). The sensors are very close to ground and there was a sensors collision on bridge ramps. Also distance between these sensors and ground is decreased and sensors are not able to detect line.

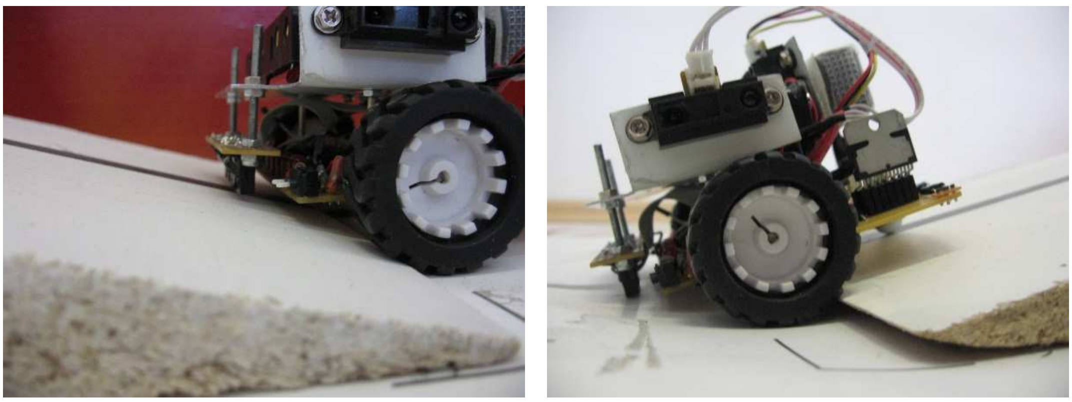

Fig. 8. Ramp problems of sensors for line detection

One possible solution is to move up sensors to distance more than 7 mm for ensuring of functionality of sensors. All line sensors have been installed on movable platform on front of vehicle (fig. 9).

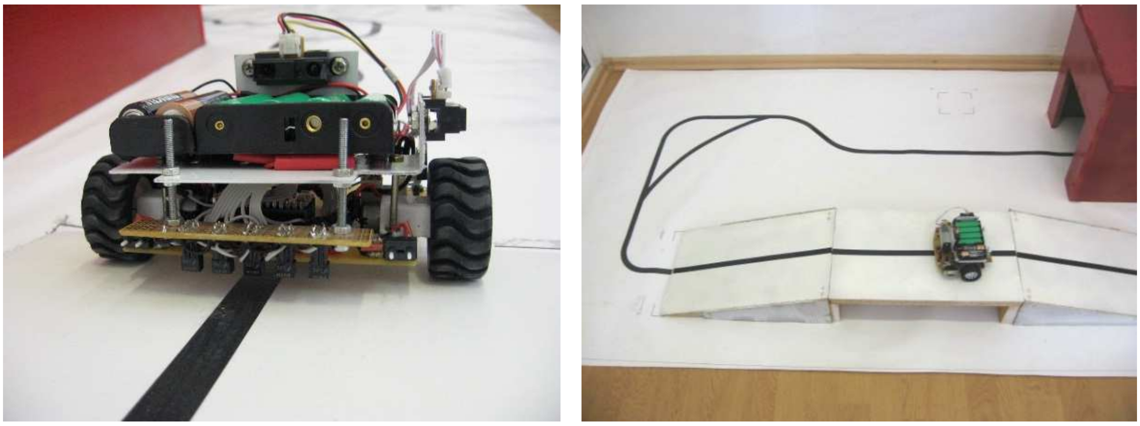

Fig. 9. Movable platform for sensors for line detection and passing the bridge

Range of distance between the 7mm and 21 mm has been measured again with modified circuits. The output of the sensor has been measured on analog input of microcontroller with 10 bit resolution. Results in decimal value of analog 10 bit reading are shown on fig. 10. It shows difference between the sensing white and black color.

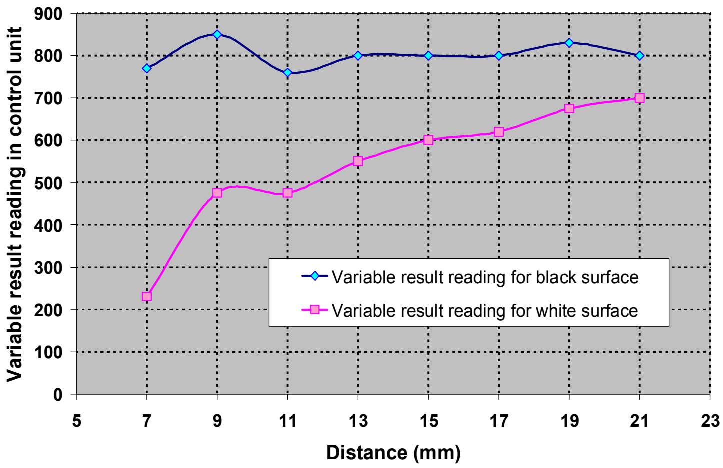

Fig. 10. Analogue readings from optocouplers placed on movable platform

Conclusion. The selected sensor system has been adapted to using of line detection. Also ramp problems have been solved. Sensors have been successfully installed on linefollower vehicle. Figure 9 shows visible difference between the voltage levels related to black and white colour line.

Future plans is to add camera vision system for automatic recognition of line before vehicle and continuously path planning. Vision systems are also frequently used for obstacle detection and mapping of environment and consequently for path planning [6-14].

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ДАВАЧІ ДЛЯ РОЗПІЗНАННЯ ЛІНІЙ

Актуальність теми дослідження. *З виробничої практики існує потреба в розробці методів подальшої навігації автоматизованого керованого транспортного засобу для виконання логістичних завдань на заводах без операторів.*

Постановка проблеми. *Різні види навігації використовуються для транспортних засобів.*

Аналіз останніх досліджень і публікацій. *Навігація цього автоматизованого керованого транспортного засобу може здійснюватися через кольорову лінію на землі або через індуктивний кабель, розташований під землею. Також використовується магніто-керуємий спосіб. Також можуть бути використані інші типи оптичних маркерів. В даний час таке застосування автономного робота зростає, тому що є потреба від промисловості.*

Виділення недосліджених частин загальної проблеми. *Навігація наступного покоління автоматизовано керованих транспортних засобів здійснюється за допомогою лазерних сканерів, які тому називаються лазерно-керованими машинами. Цей тип не розглянутий в цій статті.*

Постановка завдання. *Основна мета статті - розробка сенсорної системи для визначення кольорових ліній. Є кілька проблем у використанні цих типів давачів. Виробник зазначає, що там встановлений фільтр денного світла, але перші експерименти показують чутливість до денного світла. Ця проблема може виникнути, коли автомобіль в'їде в тунель. Наступна проблема, коли транспортний засіб рухається в гору і вниз по мосту.*

Виклад основного матеріалу. *Колір давач можна розпізнати за допомогою сенсора - відбивача оптопари, що працює в інфрачервоному діапазоні світла. Оптопара включає в себе інфрачервоний світлодіодний передавач та інфрачервоний фототранзистор, який сприймає відбите світло. Оптопари розміщені на нижньому боці автомобіля. Лінія навігації чорна, а інші ділянки поверхні білі. Оптрон, розташований над навігаційною чорною лінією, не має інфрачервоного відображення.*

Висновки відповідно до статті. *Обрана система давачів була адаптована для використання при виявленні лінії. Також вирішені проблеми з пандусом. Давачі були успішно встановлені на навігації транспортного засобу. Результати показують видиму різницю між рівнями напруги, пов'язаними з чорно-білою та кольоровою лінією. В майбутньому планується додати систему відеоспостереження для автоматичного розпізнавання лінії перед транспортним засобом і безперервного планування шляху. Системи спостереження також часто використовуються для виявлення перешкод і відображення навколишнього середовища а, отже, для планування шляху.*

Ключові слова: *давач; мобільний транспортний засіб; лінія; колір.*

Рис.: 10. Бібл.: 17.

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