

## **APPLICABILITY OF A STATIC CAMERA FOR AGVS' MATERIAL SUPPLY APPLICATION**

GÁBOR BOHÁCS<sup>1</sup>–ZSOLT GYÖRVÁRY<sup>2</sup>–DÁNIEL DÉR<sup>3</sup>–  
BOGLÁRKA OTHONICS<sup>4</sup>

**Abstract:** Automated guided vehicles' application in production facilities increases continuously. As these vehicles count as the industrialized version of mobile robots, the later ones can be regarded as the future of industrial AGVs. One of the most important issue of mobile robots is sensors. Land-based mobile robots currently use sensors for general navigational purposes, identification and range finding. Current paper surveys mobile robots' most common sensors pointing out a possible further development using a static camera.

**Keywords:** AGV; mobile robot; image processing.

### **1. Introduction**

Several ways can be chosen to supply an industrial production system with material. Since the 1970s and 80s there is a continuous demand for various automation facilities. An automated material flow is in addition a more economic solution over long time, and increases reliability of the whole material supply service. For the above demand automated guided vehicles (AGV's) and systems are used more and more frequently in the industry. These systems are already mature, in the industrial systems these are very safe to use, but let's face it, even in these days they have pretty poor material handling capability.

Mobile robot however use a lot of creative solutions in all subfields like navigation (navigation with very cheap cameras), material handling (like robosoccer), or even communicating between each other (Zigbee). However, in our opinion, the industrial utilization of these solutions are highly questionable. In this paper, we try to find an answer which technology can be advantageously adapt from mobile robotics into industrial usage. We focused basically for the sensor side of the machine. The paper not only point out an appropriate solution but describes implementation of a test system which is suitable for comprehensive testing.

### **2. Overview of the currently used sensors**

Land-based mobile robots currently use a wide spectrum of sensors. Their usage can be classified into three categories. First, sensors can be used to general navigational purposes, such as GPS signal receivers, gyroscopes, Doppler sensor etc. [9]. Secondly sensor can implement identification functions. Example for these are mainly camera-based systems, which are used for the recognition of natural or artificial landmarks, signs. Besides cameras radio frequency identification systems [1] and barcode reading can be used as well. These

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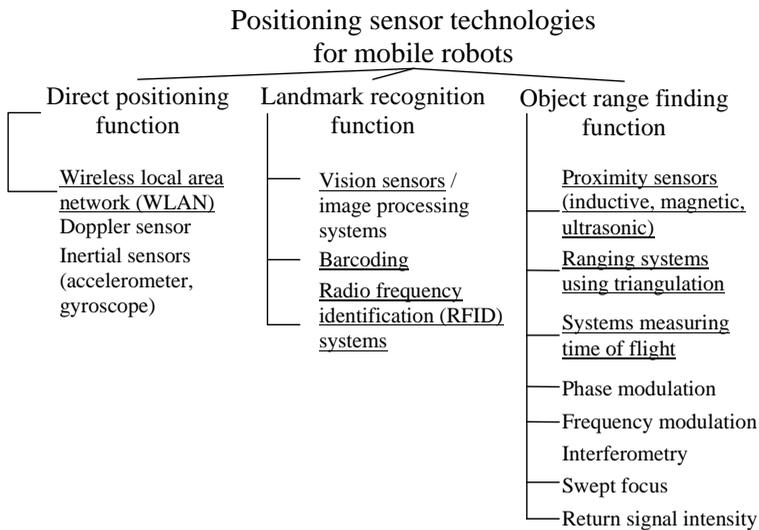
<sup>1</sup> PhD, Budapest University of Technology and Economics  
bhcsgr@gmail.com

<sup>2</sup> MSc, Budapest University of Technology and Economics

<sup>3</sup> MSc, Budapest University of Technology and Economics

<sup>4</sup> MSc, Budapest University of Technology and Economics  
H-1111 Budapest, Bertalan L. u. 7., Hungary

solutions are very widespread in the automatic guided vehicles used in manufacturing systems, however mobile robots in the research area apply them rarely. Third category – range finding sensors – contains cameras as well, however in the case of identification the camera is not used for obstacle detecting functions. A good classification of the range finding methods can be found in [2]. Figure 1 presents above classification.



*Figure 1. Classification of sensor technologies for mobile robots*

In this figure we underlined the sensor solutions which are already widely accepted for automatic guided vehicles for materials handling transport purposes in manufacturing systems.

WLAN-based positioning systems [1] can be used for indoor applications, however it must work together with other sensors, as its accuracy is limited (ca. 1 m and above). Doppler sensors' operation is based on the frequency shift if the surface is moving with respect to the emitter. Though this sensor exists since long ago, it is not used in AGV's at the industry, probably because of its price compared to simpler wheel rotation encoders. Same holds for accelerometers as for Doppler sensors, i.e. high pricing. Further, dynamic shocks from the roads quality increase measuring error as well.

Landmark recognition is one of the most reliable positioning method. This makes it very much suitable for industrial applications. There are two disadvantageous features: first, artificial landmarks must be implemented at suitable positions. Secondly, these sensors are incapable of sensing additional information such as obstacles. Single camera image processing systems belong to this class as well. These systems are capable of identifying natural landmarks and free space as well if the software enables, but the information reliability on obstacle geometry is questionable since it has no real 3D capability. Some typical camera arrangements are presented in Figure 2. Application of these sensors for mobile robots are presented in many publications, e.g. [3], [4] and [5]. Some of single camera sensors are used in industrial AGV's (e.g. [6]) but their application is limited on the recognition of artificial landmarks.

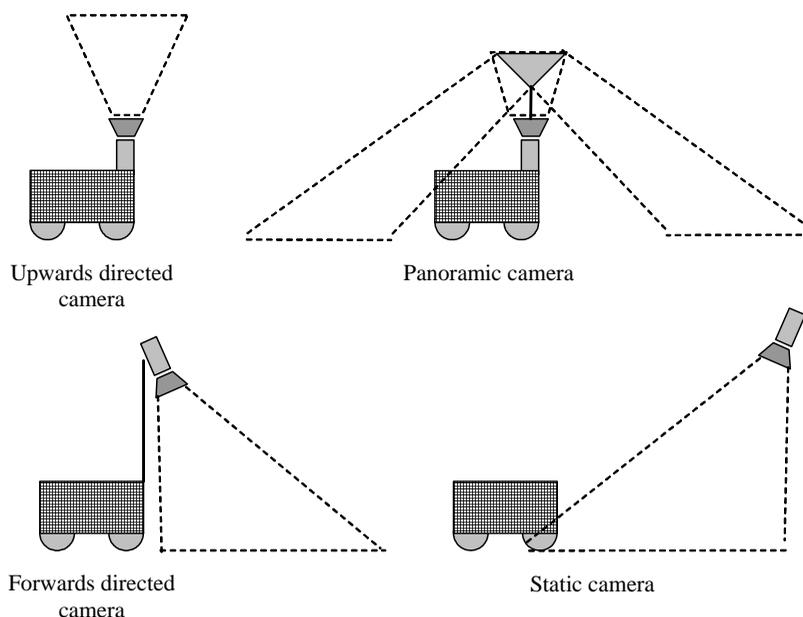


Figure 2. Typical arrangements of a single camera for mobile robots

Range finding sensors acquire geometric information from the environment. This way the safety related free space around the AGV can be checked with the same sensor. Decoding position information from the sensed contour however is a complex task. The short range proximity sensor determine only the presence of an object in the near. Inductive and magnetic sensor dispose of max. some cm range. Ultrasonic sensors detect objects up to some meters, which make them well suited to indoor AGV applications. Low price is a further advantage, but interference between multiple sensors may occur, and resolution is limited as well.

Ranging systems using triangulation use a simple trigonometric method for calculating the distances and angles needed to determine object location. An important premise of plane trigonometry is that given the length of a side and two angles of a triangle, it is possible to determine the length of the other sides and the remaining angle. There are two fundamental systems: passive and active triangulation. Passive systems are also called stereoscopic ranging systems [Figure 3. a)]. They use cameras or photo detector arrays and ambient light. The distance of an object can be calculated upon the relative orientation of the cameras.

Active triangulation systems [Figure 3. b)] use a single optoelectronic device and a controlled light source (mainly laser). Angle  $\alpha$  is measured between the optical axis of the sensing device and the direction of the light source. In this case a single sensor is sufficient, as the object's distance can be calculated from the angle of the reflected light.

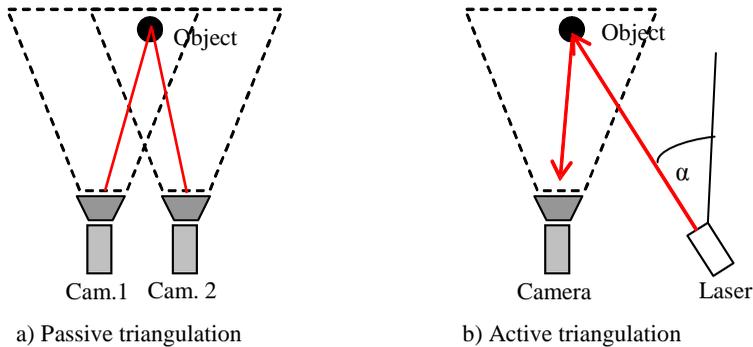


Figure 3. Typical arrangements of a single camera for mobile robots

Systems using time of flight measurements apply time measurement for an energy pulse travelling to the observed object and back. Such systems use ultrasonic or laser beams, however the first one is classified also into the proximity sensors, due to its limited range. The method's main advantage is its simplicity. The return signal comes essentially through the same path. In addition calculation of range is simpler than of the triangulation. The main usage problem of these sensor types come from the phenomenon that a portion of the emitted light became scattered. This portion of the energy causes false reflections which causes noisy data to process. Glass, clear plastic, and other transparent materials may cause problems as well.

Further listed range finding methods are less interesting for us. With phase- and frequency modulation and interferometry methods such accuracy can be achieved which is unnecessary for the conventional automatic guided vehicles' application for manufacturing. Distance measuring on swept focus requires special cameras with objectives with adjustable focus. Range of the object is given by the actual focus of the lens. Measuring method on the 'return signal intensity' is less interesting as well. Using this method the reflected signal's strength depends on the distance. Main cause of leaving this method out of scope is the lack of existing industrial applicable devices.

As seen from the previous parts each sensor has got advantages and weaknesses. Therefore it is common that robots are equipped with multiple sensors. Some good examples for that are shown in [7] and [8]. Because of the great number of the possible combinations further description is omitted.

Figure 1 shows underlined sensors that are already used in industrial AGVs. Viewing the list we found that from both the underlined and the further sensors image processing systems have the most excessive possibilities to improve the recognition capability. As seen from the classification in Figure 2. cameras have multiple possible arrangements. We selected use of static cameras as these are the least researched in the literature.

### 3. Applicability of an external image processing system for the AGV's positioning

After an intensive investigation eventually we decided it would be worthwhile to examine how to use an image processed by a visual PLC to stop intelligently an AGV at a specified point. The AGV selected was a simple magnetic tape following cost effective vehicle which

is widely accepted in industrial environment. In this case the vehicle stopping problem is one-dimensional.

We can find many examples for stopping the AGV by an external sign. The simplest way is, that we use a commando-tape to stop the AGV. There are many examples for using RF-Systems, the worker should press a button, and an RF signal will be send to the AGV to stop. But after an intensive investigation we couldn't find any such kind of solutions where the system itself decides (based on a PLC processed camera-image) if the AGV is in position or not.

The set-up experimental system is presented in Figure 4. The AGV approaches the camera as shown by the arrow at the right picture. As it approaches the stop position, the camera which is continuously searches for the match pattern finds the pre-learned marking on the AGV. The marking must have a shape which cannot be mixed up with any pattern from the environment. After finding the search model, the radio transmitter sends a signal to the AGV, which sets brake command immediately.

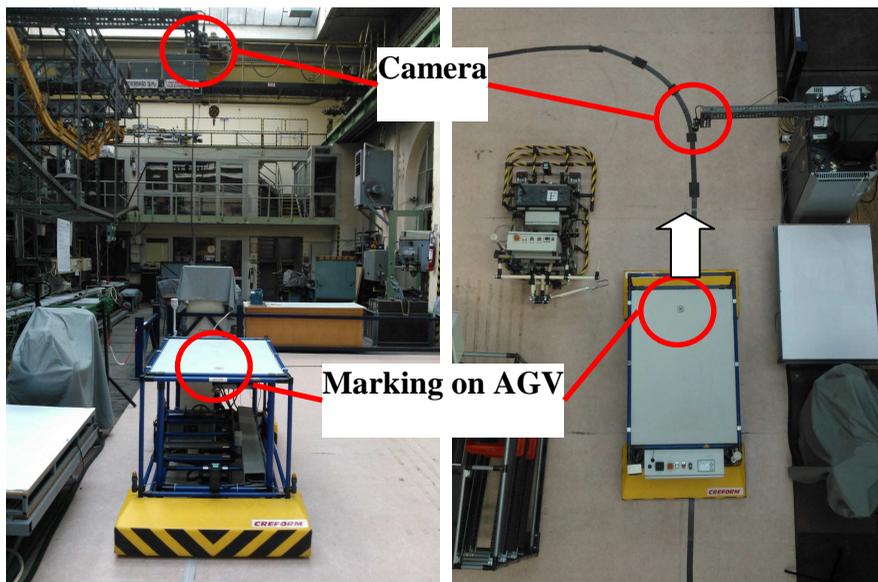


Figure 4. Typical arrangements of a single camera for mobile robots

The command causes the AGV to stop. We have conducted several experiments, which shown that the accuracy is depending greatly on the speed of the AGV before the braking take place. Further question was where the pattern should be at the of recognition in order to stop exactly the desired position. For this a teaching method has been introduced. First, the ideal desired position of the AGV must be given on the camera image. In the first braking attempt the system gives stop signal in an arbitrary chosen search pattern position, which causes stopping of the AGV at a distance from the ideal position. Using this distance error next time the vision sensor gives signal at an accordingly changed position. We noticed that this method worked well, the AGV stopped after some steps at the proper position. Further this method has the advantage that it adapts itself later to the change of the AGV's mechanical properties which cause e.g. changing of the braking distance.

#### 4. Summary

Automated guided vehicles' application in production facilities increases continuously. As these vehicles count as the industrialized version of mobile robots, the later ones can be regarded as the future of industrial AGVs. Land-based mobile robots currently use sensors for general navigational purposes, identification and range finding.

The aim of this research work was to show a possible development area for AGVs' sensor, which is intelligent but cost-effective as well. Further the developed method shows new possibilities for visual servoing of these industry material transport vehicles.

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