Solo Vision Gates Control: Simulation and Testing

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***Abstract*—The reliability of a safety sensor is strongly dependent on the range the sensor is able to cover. Safety devices for electric automatic gates, mainly photodetectors, with their reduced sensing capabilities, can not provide the complete avoidance of injuries so that to guarantee protection for people crossing the danger area additional devices must be introduced. In this paper we evaluate as safety sensor a solo vision system fitting sliding and swing gates, the most widespread gate sorts for residential, commercial and industrial automations. Two cameras are placed at the opposite ends of the gate doorway looking at the same area to be monitored. The evaluation is carried out on both virtual and real image sequences in order to verify the practical suitability of the system after the theoretical trials exploitation.**

I. Introduction

Demanding the management of gates movement to automatic systems has introduced many safety issues: once the human presence has been excluded for moving purposes, safety systems against possible hazards associated with this sort of automation (e.g. people crushing, entrapment, lifting shearing and other sorts of impacts) had to be introduced and supervised by qualified certifying bodies. The European Community has promptly responded to such requirements and May 2005 marked the end of the transition period for the gradual adaptation to European standards concerning EC marking on doors and gates. As a result, it is now strictly prohibited to release industrial, commercial and garage doors and gates onto the market without the EC marking.

The EC marking requirement renders the manufacturer responsible through the declaration of conformity it supplies with its products, which indicates compliance with EU directives. In the case of industrial, commercial and garage doors and gates, the general reference standard is UNI EN 13241-1 [1], which, if observed as intended, allows the manufacturer to enjoy presumed conformity with the following directives:

- Building Product Directive 89/106/EC [2] (for all types of doors and gates)
- Machinery Directive 2006/42/EC [3] (for power operated doors and gates)
- Electromagnetic Compatibility Directive 89/336/EC [4] (for power operated doors and gates)

These directives are of particular interest to gate manufacturers, gate installers, those involved in the commissioning of electrically powered gates, organisations involved in construction projects (including the installation of gates), and people or organisations in control of premises where people other than their own employees may have access to such gates (such as site management and/or lettings agents).

Nonetheless risks to pedestrians from crushing zones on electrically powered gates still remains a danger to deal with and some recent fatalities have brought the safety of these systems back to attention. In particular the main issue occurred concerned detection problems: the presence of people in the vicinity of the gates closing edge was not sensed by the safety systems and the closing of the obstructed gate not limited enough to avoid people entrapment. The technology employed, mainly photodetectors monitoring a straight line between transmitter and receiver, therefore demonstrated some relevant deficiencies and artificial vision systems since started to be explored as more powerful safety systems.

Starting from the work done in [5] and patented at the Italian Patent Office [6], this paper aims to explore the method applied, generalize it to create a single method suitable for the main automatic gate systems available – sliding and swing (Fig. 1) – then finally test it in real scenarios.

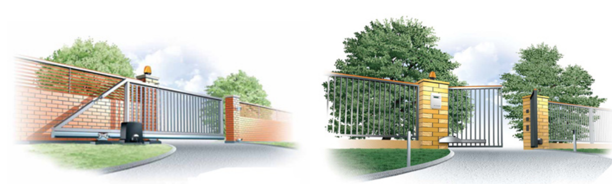


Fig. 1. Examples of most diffused automatic gates types.

II. Simulated and Real Systems Setup

A virtual model for each gate type has been produced and positioned in a simulated environment created with PreScan©, a simulation tool for the development of Advanced Driver Assistance Systems and intelligent vehicles systems[1], whereas for the real testing sessions one gate of each type was made available throughout this work by Access Automation Systems Provider FAAC S.p.A. at their headquarters in Bologna, Italy. In both the simulated and real scenarios each gate features two cameras with the same specifications (see Table I). Two NIR illuminators were also installed below the cameras in both test

[1] by TASS International, Helmond, The Netherland.

bed environments for further investigations purposes.
Cameras are positioned to the side of each gate doorway, as represented in Fig. 2 and Fig. 3.

Sliding *Swing*

Fig. 2. Simulated environment gates setup.

Left cameras *Right cameras*

Fig. 3. Real environment gates setup: sliding gate (*above*) and swing gate (*below*) with a NIR illuminator installed below each camera.

The sliding gate is 4.3 *m* wide, 1.7 *m* high and about 0.2 *m* deep, its cameras installed on a 2.55 *m* high pole.
The swing gate, considering both doors, is 3.6 *m* wide, 2.3 *m* high and about 0.1 *m* deep, its cameras installed on a 3 *m* high pole. The cameras specifications are listed in Table I. In the following sections they are referred to as "*Left*" and "*Right*" where, in our coordinates system, the *Left* camera is positioned on the left hand side of a virtual observer standing in front of the gates with:

- sliding gate case: door sliding from the observer's right hand side to the left one during the opening process
- swing gate case: doors moving away from the observer during the opening process

In the virtual scenarios the gates movement has been simulated defining its dynamics parameters for the whole image sequence duration as the doors position is fundamental in order to exclude the gates doors as obtacles from the detection area. The gates dynamics parameters are enclosed in a string written on a virtual MEF (*Master Event File*) along with the two cameras timestamps. Encoded in the string is the gates doors position minute by minute so that for each image frame the gate doors position is known.

TABLE I. CAMERAS SPECIFICATIONS

Characteristic	Value
Spectral Range	Visible
Resolution	1280 x 1024 *px*
Field of View	VFOV 99 *deg*
	HFOV 86 *deg*
Focal Length	2.90 *deg*
Frame Rate	10 *fps*

III. PROPOSED METHOD

The algorithm has been developed within the GOLD (*Generic Obstacle and Lane Detection*) framework [7]. For both gates cases the same algorithm has been applied, the core of it reported below in pseudo-code language (see Algorithm 1). The first step consists of defining the area to be searched for obstacles, then follows a calibration phase: in the case of virtual images each camera absolute parameters are known as they are set by the user during the design of the simulated scenario so that the correspondence between world and camera coordinates is totally exact.
Once the previous phases have been defined, the following steps are performed:

- removal of the distortion introduced by the lens and perspective obtaining an IPM (*Inverse Perspective Mapping* [8]) image for each input image
- *Left* and *Right* cameras IPM images difference
- segmentation process of the difference image to detect the pixel aggregations (*blobs*) in the area
- discrimination of the previous *blobs* by means of dimensions, proximity, position values

Algorithm 1 Program IntelligentGate (Output)

$sourceLeft = AcquireImage()$
$sourceRight = AcquireImage()$
$LeftIPM = ImageToIPM(sourceLeft)$
$RightIPM = ImageToIPM(sourceRight)$
for $LeftIPM.Pixels$ **do**
  $DiffIPM.Pixel[i] = ABS(LeftIPM.Pixel[i] - RightIPM.Pixel[i])$
end for
$ListBlob = FindBlob(DiffIPM)$
for $ListBlob$ **do**
  if $ListBlob[index] = isvalid$ **then**
    if $insideAreaControl(ListBlob[i])$ **then**
      $Output = true$
    end if
  end if
end for

Additional considerations must be done in the swing gate case to deal with the areas covered only by the single cameras (monoscopic areas behind the gate's doors) as each door gate occludes the opposite camera view. In such areas a background subtraction method is employed using the known gates position to decide the moment when updating the background image is suitable (gate closed and no obstacles previously detected in the monoscopic areas).

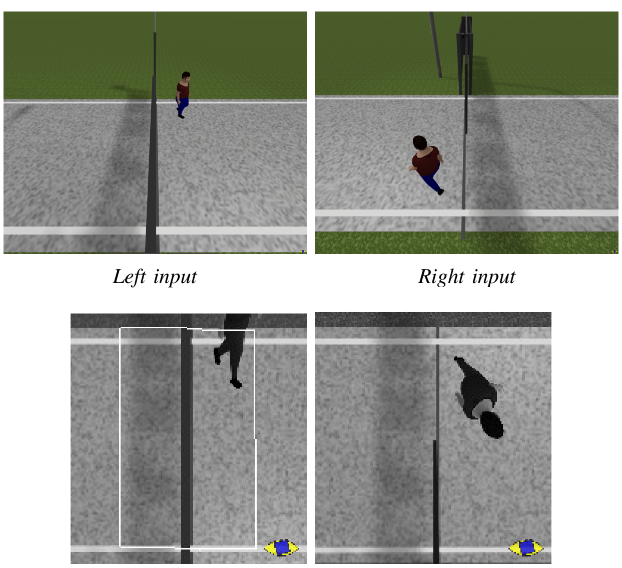
IV. Results

The algorithm developed has been tested both on virtual and real image sequences taking into account pedestrians and vehicles as obstacles during daytime light conditions only. Correct detection of the obstacles is indicated on the output image with a warning signal icon on the upper right side.
In the following results obtained are reported and commented in separate sections.

A. Sliding Gate

The danger area for the sliding gate case is the long narrow one lying on both sides of its sliding rail and is highlighted in red in the following (output images only). In standard safety systems photodetectors are placed at the border of the red area outlined so that any object or person standing in between the two straight lines monitored by the photodetectors could be in danger of crushing whereas is permanently detected by the vision system.

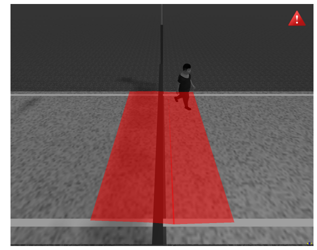
1) Simulated Environment: In this example a child walking in the photodetectors-blind area Fig. 4 is detected by the solo vision system Fig. 5.



Left input *Right input* *Left IPM* *Right IPM*

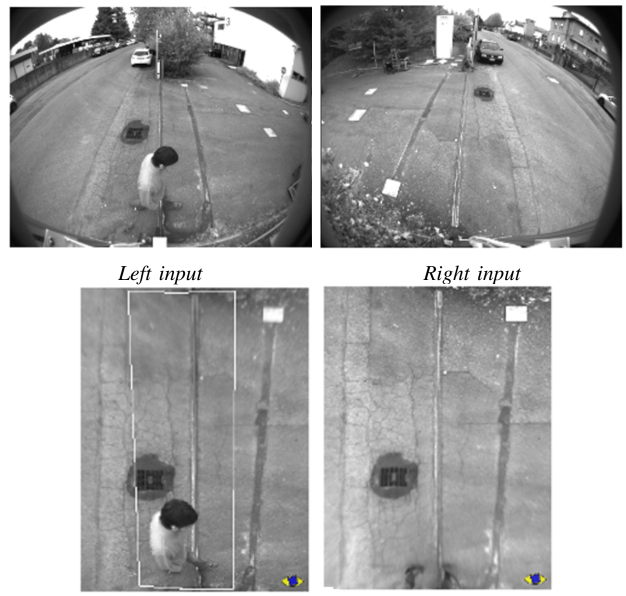
Fig. 4. Input images before and after the lens distortion and perspective removal.

2) Real Environment: For the real environment a similar situation is shown: a man crossing the gate guide rail inside the danger photodetectors-blind area Fig. 6 is correctly detected by the solo vision system Fig. 7.



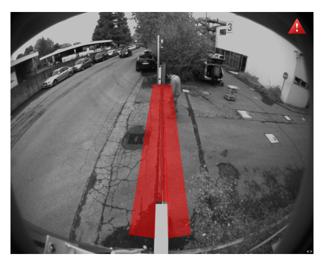
Output

Fig. 5. Processing output: detection of a pedestrian standing in the danger area.



Left input *Right input* *Left IPM* *Right IPM*

Fig. 6. Input images before and after the lens distortion and perspective removal.



Output

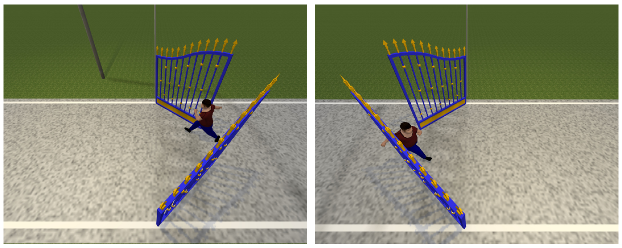
Fig. 7. Processing output: detection of a pedestrian crossing the gate manouvering area.

B. Swing Gate

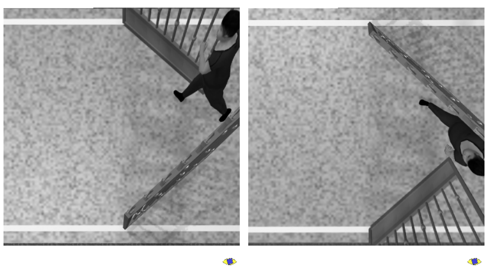
Images reported for the swing gate case include too pedestrians as obstacles.
The monitored area is defined by the maximum opening area of the doors themselves. For symmetry purposes the area monitored on the opposite side of the gates opening direction has the same dimensions.
The examples shown are aimed to reproduce some of the most critical situations to be dealt with for the standard photodetectors safety devices like the risks of impact and

entrapment during the gate doors opening/closing manouvres.

1) Simulated Environment: Fig. 8 and Fig. 10 show two cases of high impact risk for the boy running through the doors and the lady standing behind one of them during the opening process. Both people that would not get detected by photodetectors and could be crushed or entraped between the gate doors are instead correctly detected by the solo vision system (Fig. 9 and Fig. 11).

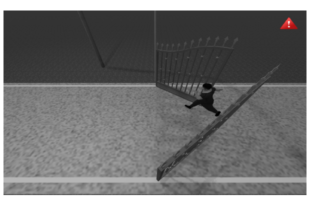


Left input *Right input*



Left IPM *Right IPM*

Fig. 8. Input images before and after the lens distortion and perspective removal.



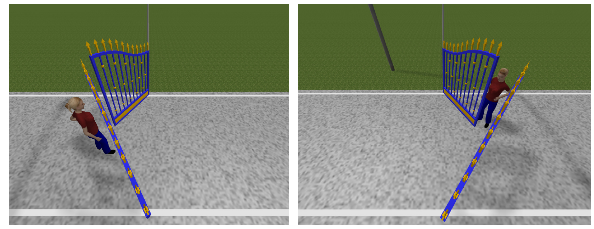
Output

Fig. 9. Processing output: detection of a pedestrian running through the gate doors outside the area monitored by photodetectors.

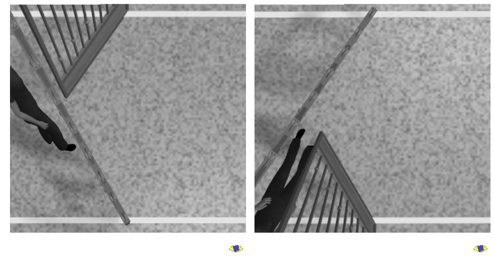
2) Real Environment: In the danger situation shown in Fig. 12 the man correctly detected in front of a door gate Fig. 13 stands in a particular area being blind both to the photodetectors system and partially blind to one out of the two vision system cameras after the IPM transformations computing.

V. CONCLUSIONS

Tests carried out on virtual images have provided some important indications about the most suitable system setup and processing algorithm to be further analyzed on real scenarios plus the suitability of a single method to be applied for both the most widespread automatic gates systems available on the market for industrial, commercial and residential automations. Together with the outline of the cameras configuration and positioning, the work carried out has allowed to take into account some of the most critical issues brought by the standard safety devices for automatic gates and experience how a vision system could instead easily deal with and solve them. Qualitative performances on the sequences acquired in real scenarios have demonstrated that a single vision system properly tuned may be suitable for different gates automations

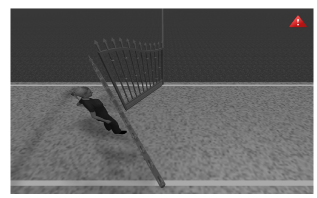


Left input *Right input*



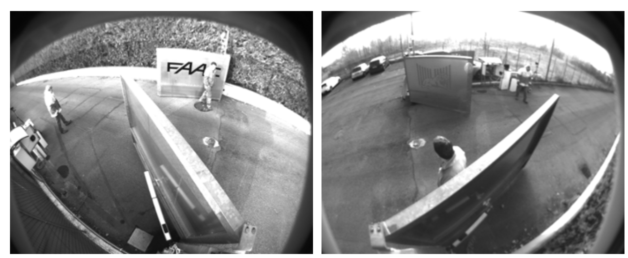
Left IPM *Right IPM*

Fig. 10. Input images before and after the lens distortion and perspective removal.

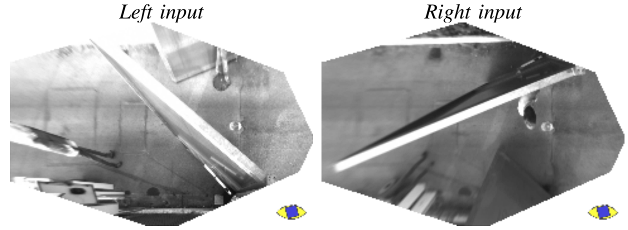


Output

Fig. 11. Processing output: detection of a pedestrian standing behind the gate doors during the opening process.



Left input *Right input*



Left IPM *Right IPM*

Fig. 12. Input images before and after the lens distortion and perspective removal.

Output

Fig. 13. Processing output: detection of a pedestrian standing between the gate doors.

and with some key advantages in respect of the other safety devices currently employed.
In particular the assembled vision system features the ability to detect obstacles:

- much earlier, with a significant increase of the automation safety level
- in a much wider area including critical zones as those lying behind the single doors of swing gates
- standing but not moving towards the gates moving trajectories, with important reductions of the power demanded for the gates stopping and reopening when not needed

Next investigations of the vision system developed will include further extensive tests to report quantitative performances in real scenarios where quick light changes, vibrations of the doors and reflections must be dealt with. A classification of obstacles will also be considered in order to further optimize the gates saftey and reduce the number of safety devices to be applied. Different light and weather conditions will too be taken into account for robustness purposes.
Some nighttime image sequences in both virtual and real environments have already been acquired by authors using two NIR illuminators as complementary devices. Such images are currently being analyzed in order to confirm the suitability of these lighting devices for the obstacles detection problem at nighttime. Processed examples on images acquired within the simulated environment are shown in Fig. 14 and Fig. 15 for the sliding gate case and Fig. 16 and Fig. 17 for the swing gate case.

Acknowledgment

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[4] ——, *Electromagnetic Compatibility Directive 89/336/EC*, 1989.

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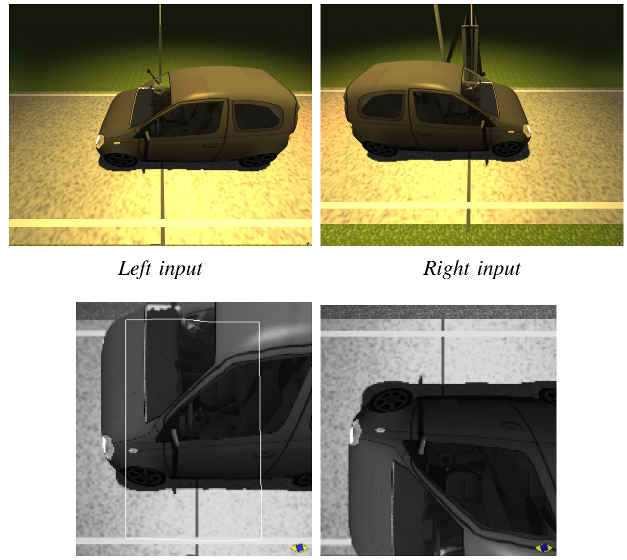
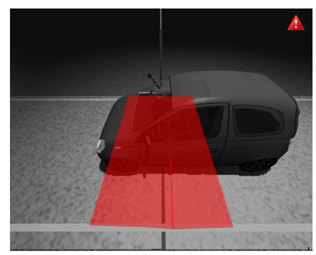


Left input *Right input*

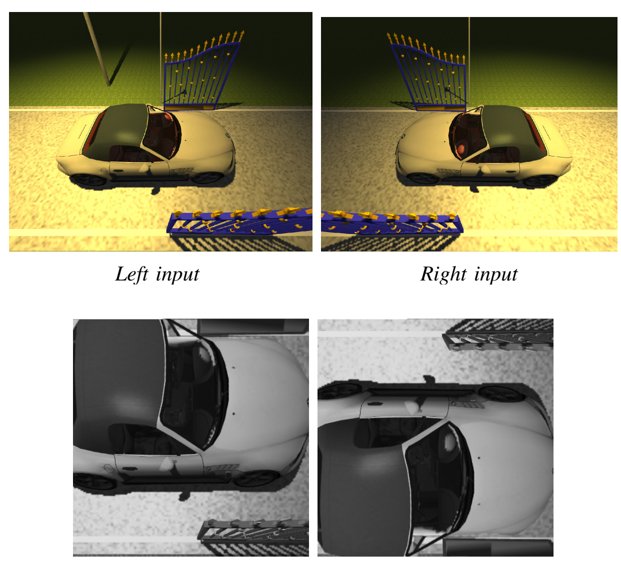
Left IPM *Right IPM*

Fig. 14. Input images before and after the lens distortion and perspective removal.



Output

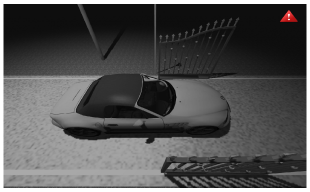
Fig. 15. Processing output: detection of a car driving through the simulated sliding gate.



Left input *Right input*

Left IPM *Right IPM*

Fig. 16. Input images before and after the lens distortion and perspective removal.



Output

Fig. 17. Processing output: detection of a car stopping between the simulated swing gate doors.

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