Novel Approach to Utilization of Differential Evolution for Camera Placement Problem

J. Sevcik, T. Urbanek,, and J. Sipek

Abstract— The camera placement within the observed area is one of the most relevant problems within the new Video Surveillance System design. Some potential to automate the camera placement within the particular area is in utilization of various optimization methods. Nonetheless, the problem of camera placement is too complex for standard analytic solution methods. Differential Evolution has recently proven to be an efficient method for optimizing real-valued multi-modal objective functions. It represents a modern heuristic approach for minimizing nonlinear and non-differentiable continuous space functions. The example of application of this method is utilized within this research paper and some interesting results were achieved.

Keywords—Video Surveillance System, Camera Placement Problem, Differential Evolution;

I. Introduction

REAL world counter the consequences of enormous amount of deployed Video Surveillance Systems (VSS), missing particular purposes even appropriate camera placement within the observed areas of interest. The importance of this problem is increasing each day, until the exact rules for VSS´s designed will be obligatory. The existence of recommendations have minimal impact on the quality of VSS, which are designed and realized recently.

This problem is well known as the Art Gallery Problem (AGP) [1]. However, it is assumed that the sensor has unlimited visibility, that is, infinite visual distance and 360-degree visual angle in the AGP [2]. In fact, visibility of camera is limited by its visual characteristics. These are calculated from hardware equipment of the camera. The necessary parameters to calculate exact polygon of camera visibility are:

- image sensor format (1/3"),
- focal length of lenses,
- aspect ratio,
- resolution in which the image is represented (to set level of detail areas).

A. T. Murray et al. have proposed new methods to calculate the optimum camera placement using the set covering problem [3], [4]. However, in their works, camera positions and pan-tilt-zoom parameters are decided separately. Moreover, the camera placement locations are limited [2].

One of the approaches how to automate camera placement within the exposed area is to use tool of Artificial Intelligence, the modern stochastic method called Differential Evolution (DE). The main advantages of this method are good convergence properties, also understanding and implementation simplicity. DE is relatively easy to work with, having only few control variables which remain fixed throughout the entire minimization procedure [5].

The unique camera placement technique is presented in this research paper. Firstly, the whole VSS evaluation framework is described. Moreover, VSS proposal criteria is established and the camera placement optimization principle is explained in next step. Standard model cameras specifications are designed in next part. Then the specification of data format and its representation for purposes of DE is provided. DE is then applied and some constitutive results have been obtained. The considerations to the extended version are discussed in final part.

II. Problem formulation

General rules to deploy efficient VSS are described in relevant European Standards. However, only brief guideline are included within these standards, which form inappropriate background for deployment of high efficient systems. There are not existing quantitative approach how to evaluate the effectiveness or quality of VSS. Besides these facts, they are real potential to improve this situation through VSS evaluation framework (VSSEF). The VSSEF consists of following steps:

a) Security assessment of the area of surveillance (AOS).
b) Calculation of risk levels within particular parts of the AOS.
c) The risk level layer design and implementation to map groundwork.
d) Calculation of environmental conditions, which influence the effectiveness of VSS within the particular parts of the AOS.
e) The environmental conditions level layer design and implementation to map framework.
f) Mathematical interpretation of AOS layout and particular layers.
g) The table of cameras proposal, including parameters which influence Image Operational Properties (IOP) of each camera. [6]
h) Mathematical interpretation of IOP related to particular camera model.
i) Using DE to design appropriate placement of minimal number of surveillance cameras to provide efficient minimization of risk within particular AOS.

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j) Verification of obtained results by appropriate methods, etc. expert assessment.

Experimental utilization of DE for purposes of appropriate surveillance camera placement within the particular AOS is investigated within this research paper. Moreover, the processes of mathematical interpretation of AOS layout and particular layer is also included. Furthermore, the camera table and its mathematical interpretation is also provided for purposes of DE´s testing.

A. AOS model interpretation

The Euclidean interpretation of AOS was chosen as an appropriate solution for purposes of this research. AOS could represent urban square, block or busy street. Considering mathematical method which will be used for the experiment, the most suitable to assess AOS "per partes"., because of ability of DE to summarizes individual subsystems to create solution for whole system. There are three principal spatial entities within the AOS:
- non-transparent structures (offered as a possible anchor for camera points, they are buildings, statues, columns, trees, etc.),
- transparent structure (all areas where the level of risk in terms of VSS is negligible),
- areas of interest (all areas where the risk level higher than negligible).

If we looked on specified model space parallel to the vertical axis z, we saw a combination of planar figures of three colors (eg. black - opaque structures, gray - transparent structure, white - areas of interest).
Since the entire model space described relatively large number of parameters, it is appropriate to use the system layers. Thus, the above structural specifications such as space will be called topological layer model.
Another layer model will map the impact of light conditions, as specified above will be either dynamically changing over time or in different modes. It is important to be aware of what light actually goes in the case of monitoring space through VSS. Always regards the position of the observer, that the camera points to the object of interest and its position relative to the light source, that is as such an object illuminated. The same applies to the position of the observer to the light source, as a direct effect of light in the optical system of the observer has resulted in degradation of the information value of the monitored scene. It is possible to mention this example for better expression: if different lighting conditions have occurred within a monitored scene, then it is much more demanding on the quality of the technological system scanning and requires the use of extra features such as hardware-implemented WDR (wide dynamic range).
All the above mentioned characteristics should include illuminating layer model, it is necessary not to forget, the differing characteristics of light when exposed to various environmental influences.
For an objective assessment of the illumination conditions the specialized tool like COMSOL Multiphysics was the most appropriate to utilize.
For security reasons, the key sheet the evaluation area, regarded to the risks involved and the nature of the relevant areas of the model. The level of risk will be defined by the following parameters:
- scene dynamics (the speed of the objects of interest),
- objects of interest dimensions and trajectories (motion vectors of objects of interest),
- results of the security assessment (build a list of threats to their assignment to particular spaces model).

B. Camera models FOV mathematical interpretation

In all six variants were used the same Full HD camera with image sensor size 1/3 ". There were always showed three dimensions and the height of the triangle forming pick-up pattern, further distance, which must be subtracted from the triangle, ie. the field that the camera can not focus, it is a small triangle just behind the camera lens. The third dimension is the width of the visual field on the edge of visibility. The dimensions of the visual fields are still heavily idealized, and therefore it would be necessary for realistic testing to fine-tune a matter detectability limit at a distance etc. For testing purposes I contracted field of vision only to the level of object recognition level observation.

Table 1 Camera models

ID	F.L. (mm)	LOS (m)	OPW (m)	UD (m)
1	4	26	34	2
2	6	39	37	4
3	8	53	35	6,5
4	10	66	35	8
5	12	81	35	10
6	14	92	35	12

All The following parameter was specified in Table 1:
- focus length of lenses (F.L),
- line of sight (LOS),
- observation plane width (OPW),
- un-focusable distance (UD).

C. Graphical setting of evaluated structures

There were several categories of evaluated areas proposed within this experiment. Particularly there are:
- Intersection,
- Street,
- Square,
- Curve.

The model areas were proposed on the basis of European standards related to road design and urban architecture to fulfill the requirements on VSS evaluation model. The graphic interpretation of evaluated areas were proposed in 2D projection for purposes of this research where the camera installation high was established on 3 meters.
The graphical base was proposed for easier and suitable testing, where the values in particular matrixes were derived from RGB colored pictures of the areas. The exact places for camera possible installation were marked as green pixels, the risky areas by red, building and nontransparent structures by black and transparent areas by blue color. Here on figures are examples.

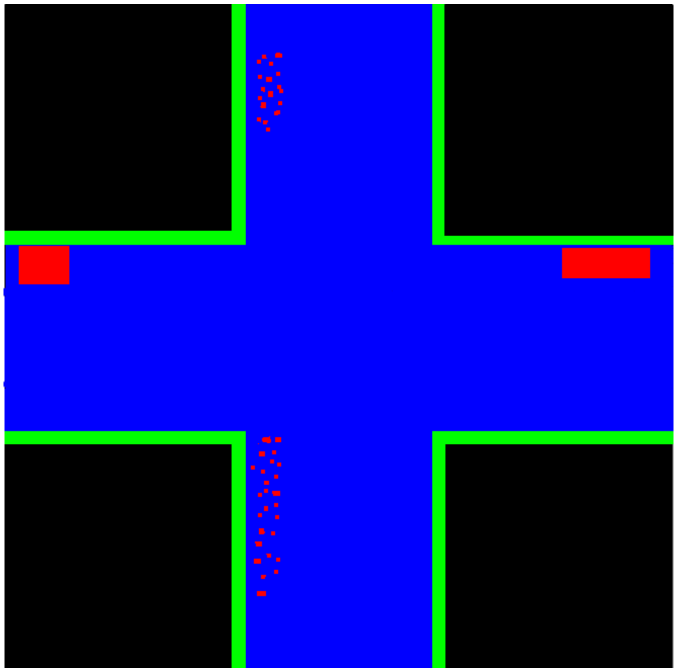

Fig. 1 The Crossroads Area of Evaluation

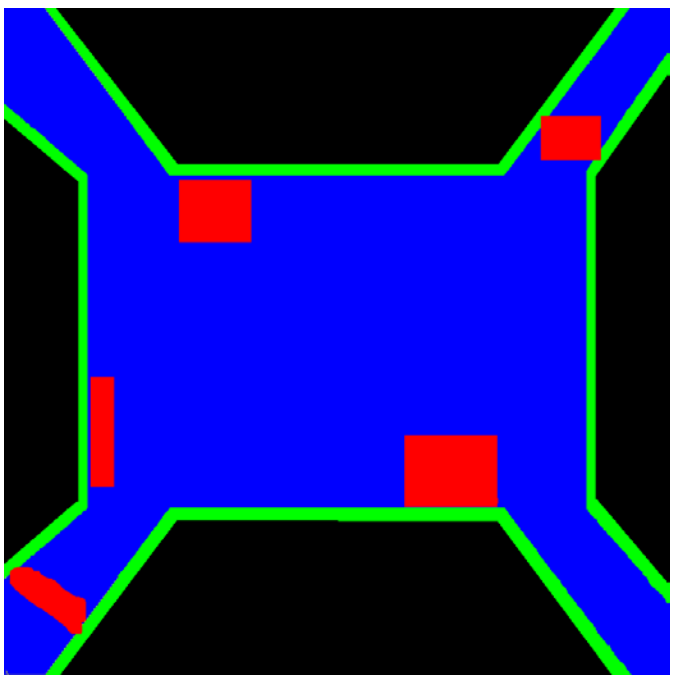

Fig. 2 Square Area of Evaluation

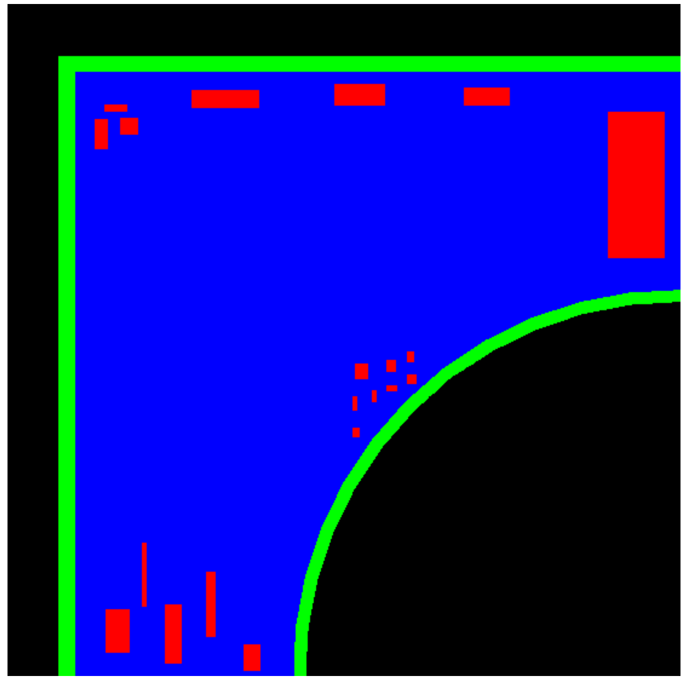

Fig. 3 Curve Area of Evaluation

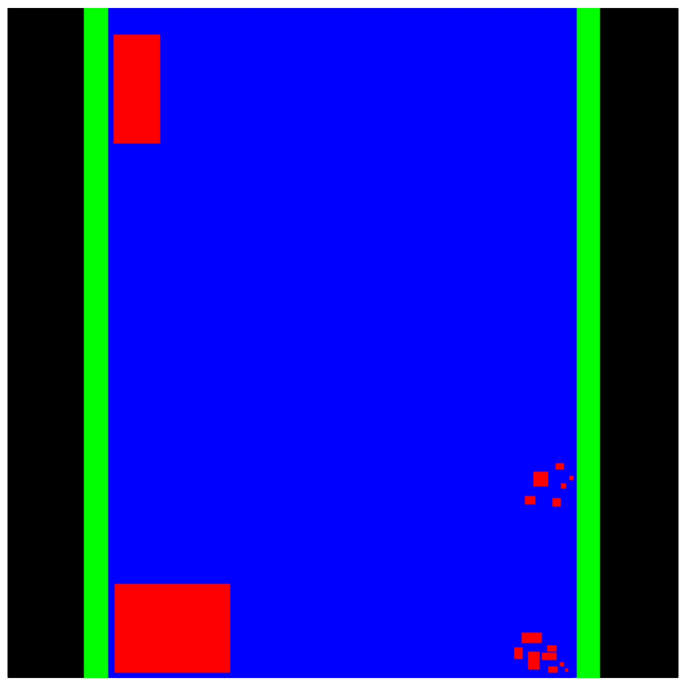

Fig. 4 Street Area of Evaluation

III. Problem Solution

The isosceles triangle was utilized for interpretation of camera field of view, because obvious similarity to its horizontal projection. There are several key descriptors to express isosceles triangle in mathematical way:

- position of the origin (x,y),
- its height and width (via. Camera models table),
- and rotation I regard of its initial position.

Data type vector {x,y} was chosen for origin position. For mathematical interpretation of height and width was also chosen vector {height, width}. For rotation the number in degrees was chosen, where the initial position is equal “0” and the axis of triangle is parallel to axis “y” of Cartesian coordinates.

All positions where it is possible to place camera is in position menu.

For example:

Positions = {{1,1},{5,6},{7,9},{6,3}} (1)

All usable types of cameras was placed to type field of cameras, for example:

Cam = {{36,95},{25,36},{12,84}} (2)

Individual for purposes of DE is then in following form:

Individual = {position menu index 1, camera menu index 1, angle of orientation 1, position menu index 2, camera menu index 2, angle of orientation 2, position menu index N, camera menu index N, angle of orientation N}.

Particular camera is then represented in Individual by three values. If we want to place to AOS 5 cameras, it is necessary to create individual about fifteen values.

DE calculation parameters was for this experiment set as you can see in Table 2.

Table 2 DE parameters setup

NP	20
Generations	60
F	0,4
Cr	0,4

The problem dimension is then related to number of cameras utilized within application.

A. *Objective function*

Objective function, the rise and fall of evolutionary algorithms. In order to be able to identify which individuals are better than others, we serve just objective function. The objective function is actually a geometric area in which evolutionary algorithms are looking for extreme, ie. minimum respectively. maximum. Each individual is assigned a utility function to obtain the so-called. Suitability. Proceed to the next generation a better individual.

The matrix N of size xn, yn is determined in this experiment. Cameras have been placed to generated positions, its particular type and orientation. There are represented as a black point within the matrix.

The description of the problem is to cover the largest area within matrix M through the utilization of cameras defined in matrix N.

$$CV = \sum_{x=1,y=1}^{xn,yn} \begin{cases} -5, & N_{x,y} = black \\ 5, & N_{x,y} = white \end{cases} \quad (3)$$

Where amount of camera equal to 5 was chosen just for this experiment.

B. *Results of particular experiments*

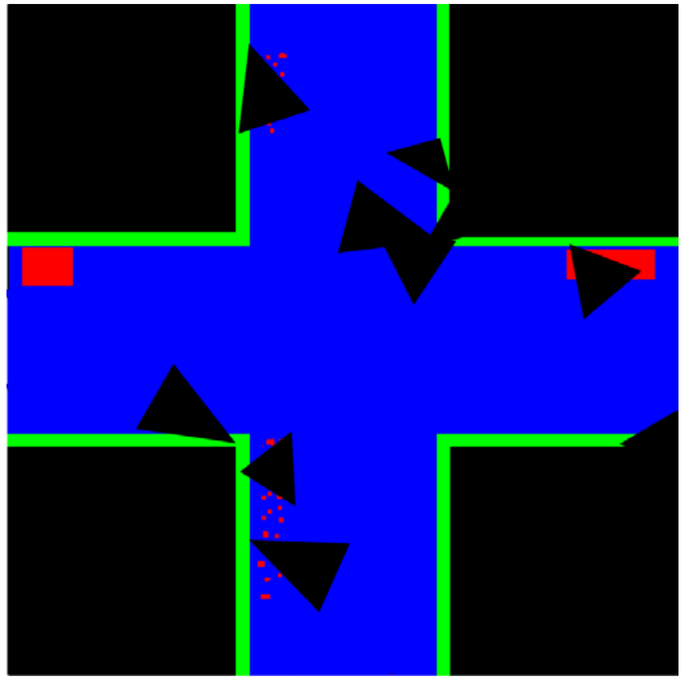

Fig. 5 Crossroads experimental results

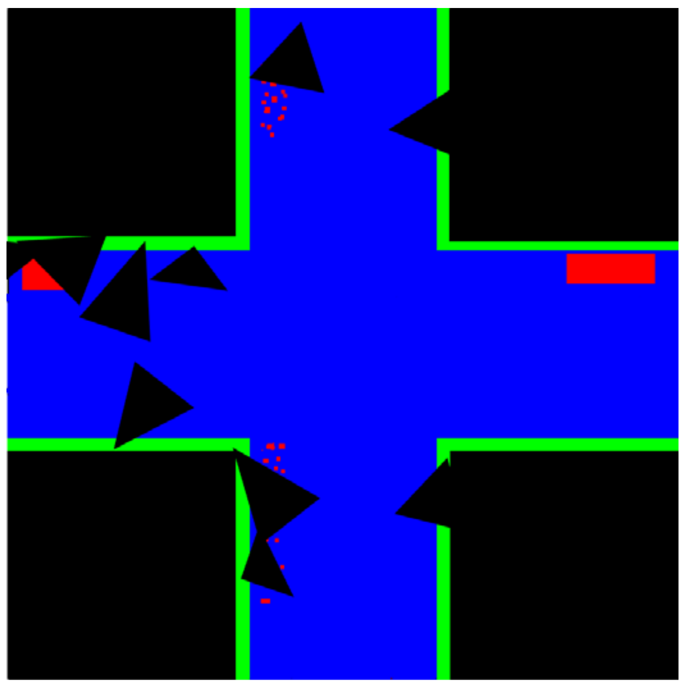

Fig. 6 Crossroads experimental results II

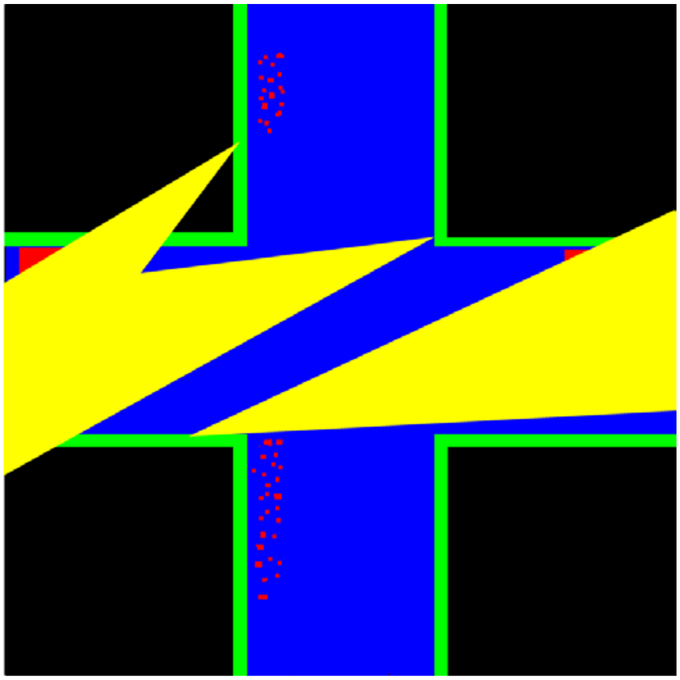

Fig. 7 Crossroads experimental results with second variety of cameras

IV. Conclusion

Possibility of application of DE heuristic method was investigated in this research paper. Whereas the setting was idealized in order to obtain some helpful results for evaluation of applicability of the method to solve this particular problem, several utilizable results were gathered. However, there are probably too many influencing factors to gain useful results by utilizing DE. Although DE method is quite useful in case of high dimensional problem solution, for correct camera placement within real environments is quite limited. Our research team has planned the utilization a standard analytic method in case of this problem but with considerably modified conditions and the AOS description.

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