Applied Soft Computing xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

Self-adjusting focus of attention in combination with a genetic fuzzy system for improving a laser environment control device system

Eddie Clemente [a], Francisco Chavez [b], Francisco Fernandez de Vega [b,*], Gustavo Olague [a]

[a] Department of Computer Science, CICESE Research Center, Km. 107 Carr. Tij-Eda, 22860 Ensenada, Mexico
[b] Centro Universitario de Mérida, University of Extremadura, C/ Santa Teresa de Jornet, 38, 06800 Mérida, Spain

A R T I C L E   I N F O

Article history:
Received 13 December 2013
Received in revised form 12 February 2015
Accepted 8 March 2015
Available online xxx

Keywords:
Self-adjusting
Focus of attention
Laser pointer
Environment control systems
Genetic fuzzy systems

A B S T R A C T

This paper presents a new algorithm capable of improving the accuracy level of a laser pointer detector used within an interactive control device system. A genetic programming based approach has been employed to develop a *focus of attention* algorithm, which works cooperatively with a genetic fuzzy system. The idea is to improve the detection of laser-spots depicted on images captured by video cameras working on home environments. The new and more accurate detection system, in combination with an environment control system, allows to send correct orders to home devices. The algorithm is capable of eradicating false offs, thus preventing devices to autonomously activate/deactivate appliances when orders have not been really signalled by users. Moreover, by adding self-adjusting capabilities with a genetic fuzzy system the computer vision algorithm focuses its attention on a narrower area of the image. Extensive experimental results show that the combination of the focus of attention technique with dynamic thresholding and genetic fuzzy systems improves significantly the accuracy of the laser-spot detection system while maintaining extremely low false off rates in comparison with previous approaches.

1. Introducction

Human beings feature both the desire and need to control the environment, probably as a result of attempting to improve their quality of life. For example, in prehistory when fire taming could mean a difference between life and death; later on history while managing and manipulating natural resources as in agriculture; and more recently with the arrival of the technological society where a plethora of electronic devices are nowadays part of our life.

Today, every conventional-home features tens of electronic devices that should be manipulated with ease. Technology should be helpful in providing smooth interaction with home appliances with the aim of transforming it into the new *smart-home* concept.

Nowadays, smart homes are particularly helpful for elderly or handicapped people [1,2], who will benefit from a proper application of technology. As a result, an easy-to-use interactive system, capable of controlling different home devices, is required.

An interactive system can be defined as: *a set of interrelated objects neatly exercising an interplay between them*. This concept can be applied to smart homes [3,4] thus providing *environment control systems*. We can find in the state of the art several approaches available in environment control systems. But we want to develop simpler interaction systems, by using a laser pointer as a basic interaction device.

The distinctiveness of our approach is the application of computer vision and computational intelligence techniques with the aim that the system should be capable of detecting laser spots and converting the signals into suitable domotic control orders. This paper continues the improving of our previous approach built on the latest results presented in [5] where different algorithms were tested to correctly detect a laser spot.

On the one hand, our earlier attempts presented in [6–8] applied several classical computer vision techniques, such us dynamic thresholding (DT) and template matching (TM), which were integrated into a decision making algorithm. On the other hand, we also analyzed the replacement of DT by a new soft computing based decision making system in [5,9–12] as well as genetic fuzzy systems (GFSs) [13–15], which in combination with TM allowed us to provide good accuracy for the problem of laser-spot detection.

Both approaches, using classical techniques and soft computing based ones, feature the same problem: TM always incur on a

* Corresponding author. Tel.: +34 924387068.
E-mail addresses: eddie.clemente@gmail.com (E. Clemente), fchavez@unex.es (F. Chavez), fcofdez@unex.es (F. Fernandez de Vega), olague@cicese.mx (G. Olague).

http://dx.doi.org/10.1016/j.asoc.2015.03.011
1568-4946/© 2015 Elsevier B.V. All rights reserved.

number of errors that are fed into the system, then making the system incapable of avoiding such errors. As a result, a number of false negatives and false positives (also called false offs) appears in the decision process. Yet, the decision making system requires such previous process that provides the values for the classification: images with or without a laser spot.

This paper presents an approach to improve the accuracy of the whole system: Instead of trying to improve the decision making algorithm, we focus on the previous techniques in charge of extracting and providing the main features required for the final decision. The main contribution of this paper is thus the application of a new genetic programming based technique, called the *focus of attention (FOA)* algorithm, capable of regulating the algorithm according to environmental light conditions with, the aim of providing better extracted features and smaller image areas. We compare the approach with previous methods and provide results that show noteworthy scores in the false offs that are maintained at an extremely low level while the new method also increases the laser-spot detection accuracy.

The rest of the paper is organized as follows: The state of the art is presented in Section 2. The classical algorithms are described in Sections 3, and Section 4 describes the whole laser pointer based environment control system. The new FOA-based approach is introduced in Section 5. The results are provided in Section 6. Finally, the conclusions are drawn in Section 7.

2. Releated works

In the literature, different environment control systems have already been described; see [4,6,16–22]. Note that, a large set of previous works, where different techniques are used, are based on laser pointers; see Table 1. In those works, the goal is to interact with a projection screen by means of the laser pointer. In our previous works, we attempt to extend similar capabilities in such a way of enhancing the interaction with devices considering a real-home environment. The idea allows users to send orders by projecting laser spots onto home devices in combination with domotic control systems [6,7,9–12,23].

Table 1 includes a summary of the previous works employing laser pointer as a pointing device. The aims of these works are to be able to control different objects (i) presented on a large display, (ii) within an environment where a robot has to pick them up or (iii) with the aim of detecting imperfections in buildings. Different techniques have been used for solving the problem of detecting the laser spot, such as threshold value, pattern recognition, colour analysis, etc. Kirstein and Müller used an algorithm divided in three phases for detecting the laser spot. The phases were, motion detection, pattern recognition and histograms comparison [24], with these techniques, the laser spot was detected only on 50% of the frames.

Another standard technique used in previous works is thresholding. This technique consists of calculating a value, using all the information that is possible to detect from the laser spot in an image. The process to calculate such value is common in the works presented in Table 1. Note that it is necessary to analyze the brightness of the image to correctly calculate the *threshold value* of the laser spot. These works are characterized by the difficulty for detecting the laser spot in environments where the light conditions are not favorable.

Other classical vision techniques incorporate a well-known algorithm called *template matching*, see [6,7,12,24–26]. In our problem a laser spot has a peculiar characteristic: it is similar to a circle. If the laser pointer is aimed directly towards a surface, a red or green circle is drawn. For this reason, authors applied different techniques to find a circle in the image. The technique consists of calculating the position of the laser spot by means of a convolutional process that searches around the whole image. Thus, the image section with the highest convolutional value is designated as the location of the laser spot.

A different technique that is also applied to detect the laser spot is employed in [27–31]. The algorithm uses different colour bands: red, green and blue (RGB) and Hue, Saturation and Intensity (HSI) to provide with a richer information that is useful for detecting the laser spot on an image. Thus, a video-camera takes a colour image in the RGB space system and the algorithm changes it to the HSI system. As a result, the laser spot is detected, by means of segmented functions or threshold values according to the applied colour system.

The main drawback in these previous works is that light conditions, orientations and textures, need to be controlled and fixed. For example, the laser spot cannot be detected correctly if there is a high brightness on a screen projection. Moreover, since previous approaches typically present many false offs, the proposed techniques require whole new processes. Table 1 presents a summary of the above described works together with others that use cameras or display filters, video analysis, camera networks, and hardware-based approaches.

We can observe that light conditions and textures are the main problem for detecting correctly the laser spot. Also, we could say that for most of the cases the algorithms work in controlled light-environment conditions. As a result, it is easier to locate the laser spot in comparison with a real home environment, where brightness of light conditions are almost impossible to control, leading the algorithms' attempt to solve uncontrollable situations.

Table 1
Q6 Previous works were based on expensive camera filters, multiple cameras and computers, as well as specific hardware and software.

Technique Used	Works
Thresholding	[27,28,32–36]
Template matching	[6,7,12,24–26]
Colour-based techniques	[27–31]
Camera or display filters	[23,37–43]
Video and camera network	[32,34,38,44–49]
Hardware-based approaches	[30,50]
Classical vision techniques in combination with fuzzy rule-based systems	[5,7,9–12]

3. Classical vision techniques

We describe here some of the classic computer vision techniques we have employed as our base case for comparison. As described above these techniques have been frequently employed before, (see Table 1), and allows us to compare their behaviours. Moreover, we already considered such techniques in some of our previous works [5–12].

3.1. Dynamic thresholding

Dynamic thresholding was the first algorithm that we applied for image feature extraction and it was also considered as the basic routine for the decision making system. Such algorithm applies a threshold value to extract candidate pixels for laser-spot detection. Fig. 1 shows two images with a laser spot for different lightning conditions. We observe that the laser spot has different sizes depending on: the light conditions and distance to the wall; hence, the two affect how the spot is projected into the camera. Moreover, laser-spot pixels also feature different energy values; hence, it was necessary to establish a dynamic threshold value that adapt according to light conditions.

In a first step, the algorithm tries to calculate the threshold value; then, pixels under this value are eliminated at the time of

Please cite this article in press as: E. Clemente, et al., Self-adjusting focus of attention in combination with a genetic fuzzy system for improving a laser environment control device system, Appl. Soft Comput. J. (2015), http://dx.doi.org/10.1016/j.asoc.2015.03.011