Possibilities of recognition and detection of combustible material in the space using by infrared camera

M. Struška, J. Struška, and M. Popelka

Abstract— The thermal images are produced from real working thermo vision cameras, which work as electro-optical imaging systems, sensitive to the mid and long wave infrared radiation, that generates images of the observed scenes, by using the thermal radiation emitted from the scenes. Article deals with proposal of intuitive fire system detection in a scene using the infrared camera. Discussed about method of algorithm for fire detection thermography image using mathematical and simulation program MATLAB/Simulink.

Keywords— Thermo Vision Systems, Thermal Image Sequence, Fire Detection

I. INTRODUCTION

Thermo vision is branch of science which analyzes the distribution of temperature field on the surface of the body using non-contact manner. The main task of thermography is analyze infrared energy radiated by the body. Using thermographic measurement system can be viewed temperature field of measured object, but only on its surface. The main advantages of using Thermal images is the ability to see objects, people and potential fire even in total darkness. The applications of thermal imaging technology is quite wide: military or police systems, security systems, industrial control systems, medical systems, etc. [1] The idea of motion detection or potential fire in a building can be analyzed in several ways, such as: methods of differentials, matching methods, spectral methods like Fourier methods. [2] All of these methods can be applied also in thermo visual systems for motion detection with some modifications typical for thermal images. The choice of a concrete method of motion detection in a real working thermos visual system can be made analyzing the advantages and disadvantages of the well known motion detection methods for visible images. For a more accurate analysis is discussed in this article method of algorithm for fire detection thermography image using mathematical and simulation program MATLAB/Simulink.

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Martin Struška is with Department of Automation and Control Engineering, Faculty of Applied Informatics, Tomas Bata University in Zlín, Czech Republic (corresponding author, e-mail: mstruska@fai.utb.cz).

Miroslav Popelka is with Department of Automation and Control Engineering, Faculty of Applied Informatics, Tomas Bata University in Zlín, Czech Republic (corresponding author, e-mail: popelka@fai.utb.cz).

Jan Struška is with Department of Automation and Control Engineering, Faculty of Applied Informatics, Tomas Bata University in Zlín, Czech Republic (corresponding author, e-mail: jstruska@fai.utb.cz).

II. MEASUREMENT SYSTEM

A. Fire characteristics of combustible materials and building products division by class flammability and reaction to fire.

1) The flash point

Flashpoint is the lowest temperature at which a flammable under normal pressure develops so much flammable vapor that these mixed with air in the short approach precisely defined open clematis briefly ignite, but do not afire anymore.

At temperatures below the ignition temperature of the ignition is not possible, because the vapor pressure of the substance is too small to create a flammable mixture of vapors with air. This does not mean that at temperatures below the flashpoint fire hazards exist. The source of ignition substance can be rapidly heated to its flash point.

2) The burning temperature

The burning temperature is the lowest temperature of the flammable substance at which the flammable vapor form so that these pairs when approaching open clematis themselves ignite and continue to burn.

Upon reaching the combustion temperature evaporation rate is at least as large as the combustion rate, so that the steam is further formed in sufficient quantity and self-combustion is further maintained.

3) Ignition temperature

The ignition point is the lowest temperature at which, under defined test conditions of flammable mixtures with air alone without initiation ignites. As ignition is called start the chemical reaction of gas or vapor mixtures with air under discovery open flame. When determining the ignition temperature of the ignition activated only by heat rather than an open flame or spark.

Reaction to fire according to flammability
A1,2 - non-flammable
B – flammable with difficulty

C – heavily flammable
D – medium flammable
E,F – lightly flammable

Table I class of reaction to fire

Class A1

Products no-contributing to fire in any of its stages, automatically deemed to comply with all requirements of the lower classes.

Class A2

Natural building stone (Slate, marble, sandstone, granite), concrete heavy, light porous (aerated concrete, foam concrete) as lightweight aggregates (agloporitem, diatomaceous earth, perlite), building materials made of clay (bricks, blocks, tiles) etc.

Class B

Slabs of inorganic materials with surface finish (drywall) rigid polyvinyl chloride (PVC).

Class C

Grown deciduous wood (beech, oak), plates of laminated wood (plywood) hardened paper (ecrona, formica), organic-fiber (felt boards the hair), cast polyester laminated flooring.

Class D

Chipboard for general use (PCB stamped) wood-fibre board (duplex), plates of vegetable matter (SP-type cork boards, cork parquet).

Class E

Products capable of withstanding exposure to a small flame for a short period of time without significant flame spread rubber isolation foil, foil coverings of plastics and rubber (rubber floor pattern, rubber isolation carpet for electronics).

Class F

Products that do not fit into any of the previous classes.

Ignition temperature of certain substances			
Title	**°C/°F**	**Title**	**°C/°F**
Wood	270/518	Paper	Over 185/365
PVC	370/698	Cloth	Over 290/554
Perspex	460/860	Petrol	470/878
Cotton	450/842	Disel	250/482
Straw	310/590	Hard coal	350/662
Tabacco	175/347	Lignite	260/500

Table II ignition temperature of certain substances

4) Auto-ignition temperature

Auto ignition temperature is the lowest temperature at which the starting substance without external heat supply exothermic processes that lead to auto-ignition. The heat required to ignite the substances arises from the substance itself as the result of chemical, physical or biological processes.

For a safe temperature at which a substance can be heated, is considered the temperature, the value of which does not exceed 90% of the auto-ignition temperature.

5) Glowing temperature

The glowing temperature of solids is the lowest temperature at which the flames without the action occurs incandescence. Glowing may occur especially in dust and fine bulk materials. Glowing temperature is dependent on the thickness of the dust layer.

Sources of ignition may be free hot surfaces (pipes, radiators, etc.).

B. Image Processing of thermal images using mathematical and simulation program MATLAB

Load the image, store it in a 2D array. The next step is thresholding thermal image. Aside from our interest in those pixels that are below our defined value that is subtracted from the warmest found pixel, which is larger than the brightest pixel calibration (the ones that are so cold compared to the warmest pixel that are not interesting for us). Now get rid thermal image noise. Remove those areas of pixels that make up the least square (pixels are square in shape), which define as the noise floor. It can happen (and it happens almost always) that the scene will have more potential targets. If we now calculate the surface center of gravity, it may be outside an object in the scene left (if one not significantly greater will be very close to each other, the scene will be in one plane in an odd number). Filter out the scene that the field of view of a 2D matrix remained only one object -> greatest = closest, most dangerous. After this selection can already be calculate the center of gravity of the area that represent the coordinates of the remaining pixels.

Center of gravity in the individual coordinates calculate by following equation:

$$Tx = \frac{\sum_{i=1}^{n} x_i * m_i}{m} \qquad Ty = \frac{\sum_{i=1}^{n} y_i * m_i}{m} \tag{1}$$

Where n is the number of remaining pixels, x_i is the i-th coordinate x, y_i is the i-th coordinate y, mi is the i-th value of the gray level am the sum of the level of the entire area. (1) If we know the size of the thermal image (resolution matrix detector), can be determined deviations from the centers of gravity of the optical axis, as follows:

$$O_x = T_x - \frac{x}{2} \qquad O_y = T_y - \frac{y}{2} \tag{2}$$

Where x is the size in the x-coordinate (image width) and y is the size in the y-coordinate (height of the image). The minus sign means are at the center of gravity is located on the optical axis of the IR camera left (x-coordinate) or the top (y coordinate). For the plus sign is reversed (right down to the x coordinate for the y coordinate). (2) While watching the object, we will try to achieve zero deviation.

Image processing of two thermo images to determine the distance objectives:

C. Digital signal processing of the two sensors to determine distance of dangerous object.

It is virtually the same procedure as given above with the difference that a pair of thermal process, whose center of gravity compared with each other. According to their mutual position passively determine the object's distance from the plane of the objective lens. Sensors are placed in the frame in the same horizontal position but different vertical position. We have to use the same IR cameras with identical computational algorithm of gravity of the object. The small difference in these parameters takes a big mistake to determine the actual distance of the object being tracked. We adjust the relationship of the equation for the calculated pixel values of the centroid, with which we find the distance at which the tracked object is:

$$z = \frac{b * f}{|T_{x1} - T_{x2}| * k} \quad (3)$$

Where (3) b is the distance between optical axes IR cameras, f is the distance between the plane of the lens and the sensor, T_{x1} is x-coordinate of the center of gravity of the object pursued by the first IR camera, T_{x2} is x-coordinate of the center of gravity of the object observed IR camera and the other is the size of one IR detector from which is formed by the IR chip.

D. Passive distance measurement using IR cameras

This passive method of measuring the distance to an object is based on the derivation of the distance of the pairs of images obtained with two cameras, which are stored in the same vertical position and different horizontal position. The value of each pixel is a function of the distance of the corresponding real points on the observed object. Two IR cameras, which are spaced in a horizontal position spaced by a known distance b whose image plane located in the same common plane. Plane passing through the center point of the camera and the scene called epipolar plane and the intersection of this plane with the image plane is called epipolar line. Positions the two cameras are set up that each point in the scene displayed on the same row in the both cameras, and differs only by the position in the column. Two points that are projections of the same point in the scene, called conjugate pair and the distance between them disparity.

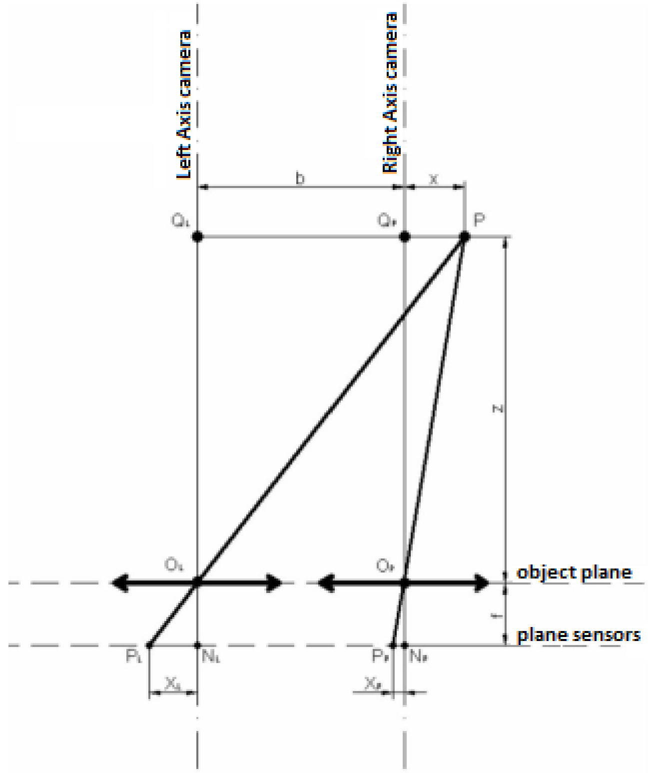

Fig 1. Use similar triangles in range

From Fig. 1, we can say that:

$$\Delta P_L N_L O_L \approx \Delta P Q_L O_L \quad (4)$$

$$\Delta P_p N_p O_p \approx \Delta P Q_p O_p \quad (5)$$

From the previous equations can be derived two basic equations:

$$\frac{f}{z} = \frac{x_L}{x + b} \quad (6)$$

$$\frac{f}{z} = \frac{x_p}{x} \quad (7)$$

After expressing x from equation (7) and substituting into the equation (6) we obtain the following relations:

$$x = \frac{Z \cdot x_p}{f} \quad (8)$$

$$\frac{f}{z} = \frac{x_L}{\frac{z \cdot x_p}{f} + b} \quad (9)$$

After modifying get:

$$z = \frac{z \cdot x_p + b \cdot f}{x_L} => z \cdot \left(1 - \frac{x_p}{x_L}\right) = \frac{b \cdot f}{x_L} => \quad (10)$$

$$=> z = \frac{b \cdot f}{x_L - x_p}$$

From equation (10) that the distance of the reference object is dependent on the disparity corresponding to a pixel of the distance from the lens plane and the sensor plane of relative distance IR cameras. The distance from the plane of the chip plane of the lens will be changed only with adjusting the distance, in a small range. Disparity of pixels is also small, because it will be different only a few pixels (depending on the resolution, the higher the resolution of the chip, more accurate distance). Parameter b is the distance between the impositions of IR cameras. This parameter can most influence the accuracy of the distance. The higher is the distance IR cameras that can accurately determine the distance of the object. Always is necessary to choose a compromise, IR cameras cannot be placed too far apart (field of view would no longer overlap) the focusing optics has given limit. The higher resolution of the chip more expensive the IR camera (is needed two identical).

III. THERMO VISION IMAGE PROCESSING FOR FIRE DETECTION

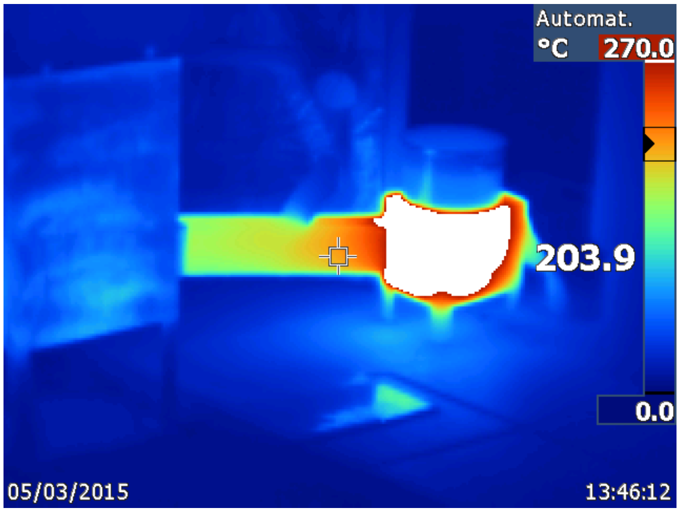

Fig. 2 thermo vision image processing 1st stage

Load the image and convert it to grayscale palette. Each pixel is represented by a pair of coordinates defining its position, and a numeric value in the range 0-255, corresponding gray level (0 represents black, 255 white). Save the image into a 3D array (x-coordinate, y-th coordinate, gray level). For converting color image to grayscale image conversion method we used standard CIE (gray = R * G * 0.2126 + 0.7152 + 0.0722 * B), where R is the red component palette, G (green) and B (blue). At the same time also saves the value of the gray levels hottest pixel in the scene, from which we subtract thresholding value, and thus we find the value of the coldest yet crediting pixel.

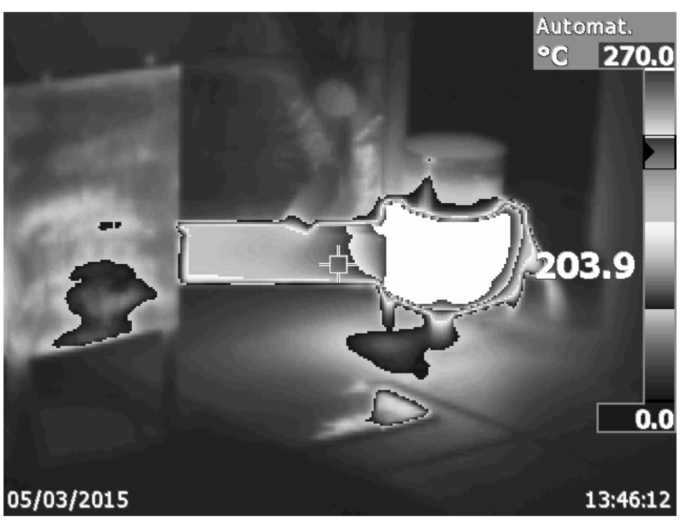

Fig. 3 thermo vision image processing 2nd stage

Using warmest pixel values from the previous stage and specified threshold (threshold gray level indicates the interval from the warmest pixel to the cooler, which will still be included in the calculation) shows how many pixels will be stored in the field and according to this data it will create for us crawled still field the size of the entire image. Now we focus on the entire field and record only those pixels that are satisfactory to us.

The range of individual components:

- Red <128, 255>, weight representation corresponding to this interval is ramping <0; 254>
- Blue <0; 127>, weight representation corresponding to this interval is linearly decreasing <254; 0>
- Green <31; 223>, the corresponding weight representation is ramping <0; 255> interval <31; 127> and linearly decreasing <255; 0> interval <128; 223>

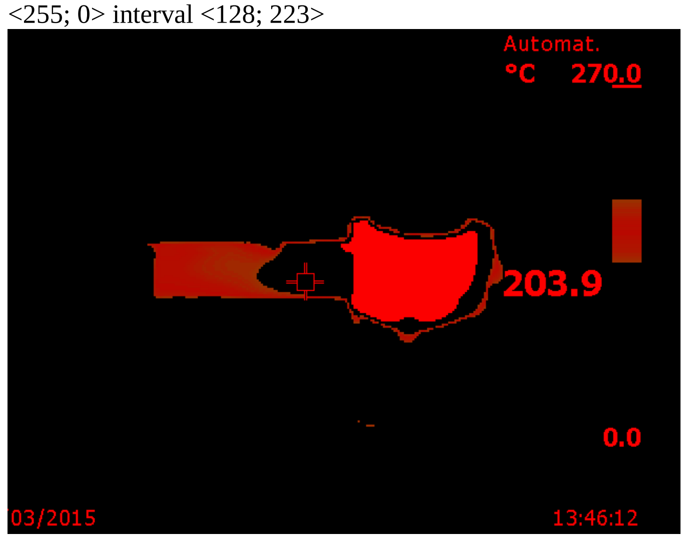

Fig. 4 thermo vision image processing 3th stage

Filter out noise from the image. Size noise specify using a number which tells us that the square of the size of the part number entered will still be considered as noise. This square will not be included in the calculation. The first is tested the levels of gray in row coordinates. If is find next to each other (in columns in the same row) more pixels than the size specified noise data we leave, otherwise erasing. Then is going to be tested field in the column coordinate. First rank array by rows, then by column. To test whether the pixels above the other (in the same column and row increasing by 1), need to sort array conversely (sort by columns first, followed by rows). While it's sorted, tested similarly as in the previous case, if the superimposed pixels more than the noise value. If so, leave them, otherwise discarded.

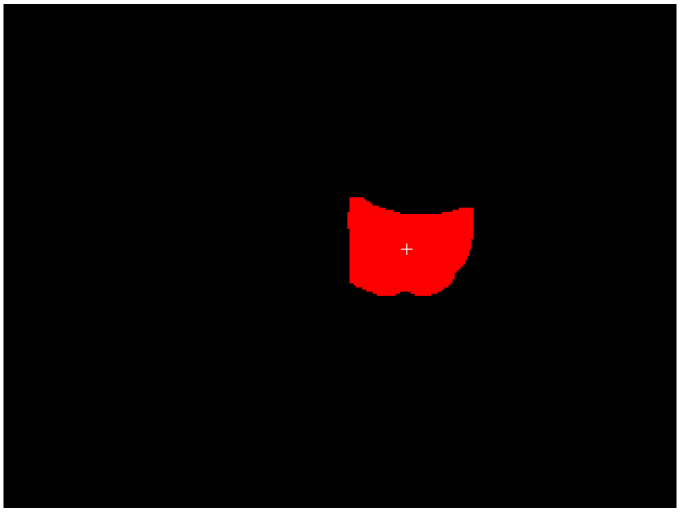

Fig. 5 thermo vision image processing 4th stage

From the filtered image, select the largest, in most cases the closest object and focus on it. We set the maximum variance that is allowed for one continuous object. In other words, unless the row (column) coordinates are remote from the previous row (column) coordinates more than the specified maximum variance, consider these pixel by pixel one object. We will continue in the first row coordinates, therefore, we will examine whether the row coordinates increases up to a specified maximum variance. Consider another cluster of pixels as a new object. Always store the start and end of row coordinates, we can evaluate at the end of which object is the coordinate of the largest (highest).

After evaluating the supreme object we only work with this area. In the column coordinate it may be more objects, as in the previous case, we will be working here. Field have to sort that we have ranked first column. After finding the largest object in the column coordinate (widest), again everything outside this area aside from the calculations. Now, it could happen that the exclusion of some areas from the column are created multiple objects in a row coordinates. Therefore, this cycle repeats until the scene has less than a single object.

From the final field that left is necessary calculate the center of gravity of the area and the center of gravity deviation from the optical axis. In the final image, the position of the center of gravity plotted cross.

IV. DIGITAL SIGNAL PROCESSING OF TWO SENSORS FOR DETERMINING THE DISTANCE OBJECTIVES

Images are from a single IR camera and adapted so that are horizontally displaced coordinate (the principle of passive distance measurement). Atmosphere has no effect on images, but there are perfectly offset exactly by x pixels, which is main part of this measurement, which is sub-pixel accuracy. Exact moving the image to x pixels is not the CG determined by a rational number, but a whole number. That is why determination of distances at higher distances on the wrong level.

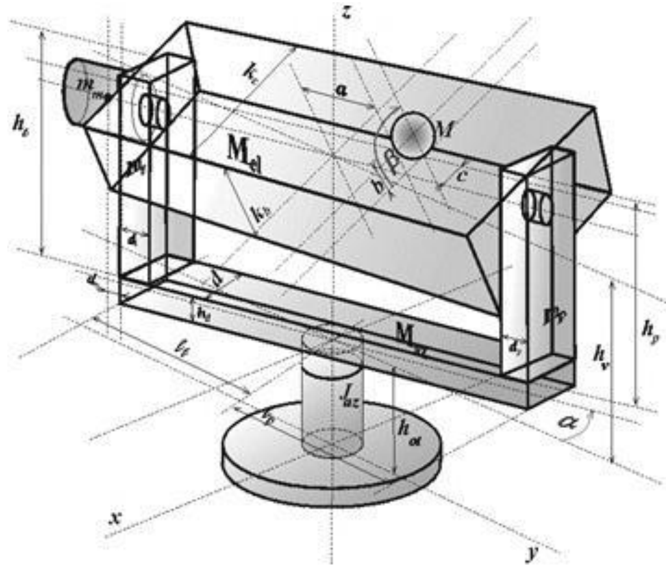

Fig. 6 Schematic arrangement motion system of one camera

At the real assembly with this type of distance measurement achieves an accuracy 3 meters at a distance of 3 km, which is excellent.

Real system (parameters was used in the real program) is in the Fig. 7. Photography was taken at the University of Defence in Brno (with permission).

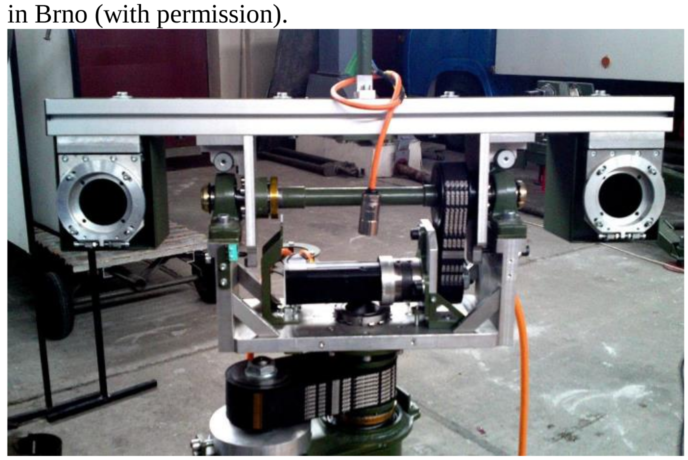

Fig. 7 General view at the system - two cameras connected together

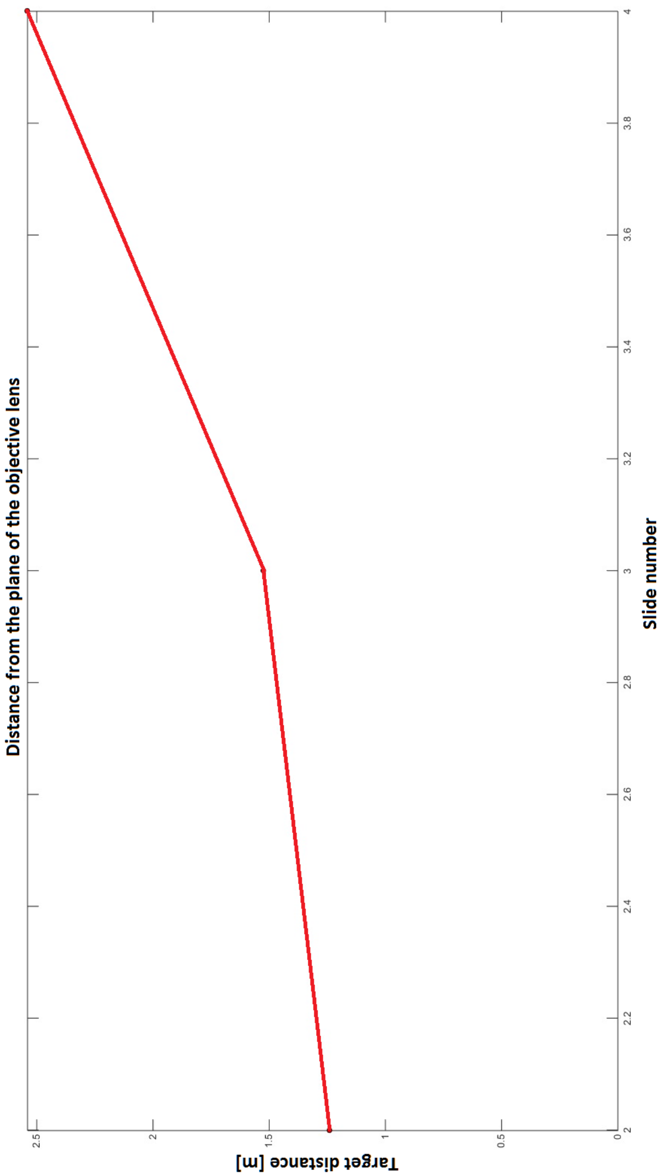

Fig. 8 Measuring target distance from the plane of IR camera

On the picture Fig. 8 is able to see centroid distance pair of pictures (each pair of frames removed a pair of IR cameras at the same time) in both coordinates. IR cameras are fixedly mounted and the vertical coordinate is not moved. The actual distance from the plane of the objective lenses, was calculated as described in Section D. Decreasing distance of the reference object (increasing the spacing of the respective centers of gravity) increases the precision with which we can determine the distance of the target. From the picture is obvious that a dangerous object is at a distance of 1.5 meters.

V. Results and Conclusion¨

The proposed algorithm for thermo vision images fire detection programed in a mathematical and simulation program MATLAB/Simulink is examined with a lot of test thermal images sequences. The time of the calculation is moving on the applicable resolution (640x480 pixels) thermal images around 20-30ms. These results are of practical use more than the other one is sufficient. With increasing resolution, with respect to the used method, times grow linearly. For brevity here in this article are presented only some parts of input (Fig. 2) and outputs (Fig. 5) sequence of frames from a whole used in one of the experiments test thermal images sequence. All experiments are carried out with test thermal images sequences from a real working thermal image camera Fluke Ti9. During the measurement distances has been found that dangerous object is at a distance of 1.5 meters.

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