VISION SYSTEM APPLIED TO DETECT SCENERIES CHANGES IN SPACE VEHICLES PLATFORMS

Barbosa, S. A., silvana@iae.cta.br
Bizarria, F. C. P., fcpb@iae.cta.br
CTA/IAE - Instituto de Aeronáutica e Espaço – Pça Mal. Eduardo Gomes, 50 – São José dos Campos – SP – Brazil

Rosário, J. M., rosario@fem.unicamp.br
UNICAMP/FEM/DPM - Universidade Estadual de Campinas - Rua Mendeleiev, s/n - Cidade Universitária “Zeferino Vaz” – Barão Geraldo – Campinas – SP - Brazil

Abstract. *The non automated continuous task to detect changing scenes in an environment can cause mental and physical stress in human operators. The mental stress with the difficult tasks of some operations, are challenges those can be reduced with efficient automation. The precision level in the detection of change sceneries depends on the final application. It is necessary to implement specific techniques adapted to the case, thus avoiding not expected results. Generally many image processing techniques presented in literature are validated through application prototypes using artificial vision. The planning and programming of machinery controlled by computer require knowledge about the working environment. Where the scene presents a less dynamic behaving, from the same orientation (position of camera and objects) and the same environmental conditions (lighting, shadow, occlusion), relevant information of the image may be obtained. Among the several possible applications of this system, which combines vision computational techniques associated with automation, this work presents a study directed to the aerospace application, which proposes to detect movement in an environment that contains platforms used in the integration of space vehicles. In the operation of that vision system, tasks related mainly with the detection of scenery changes and the registration of these images, are done through the implementation of dedicated algorithm. The implementation of that algorithm uses techniques of image processing based on spatial filters, especially denominated by spatial convolution average filter. The tolerances and filters applied in images treatment avoid the detection of minimum differences that are not the focus in this application type. The image processing is characterized by specific solutions, that is, techniques that work well in an application, could not be appropriate in another one. The obtained results indicate the proposal is appropriate for the studied application.*

Keywords*: vision system, space vehicles, sceneries changing*

1. INTRODUCTION

The use of vision or other types of sensors is motivated by the constant need of increasing flexibility on robotics application (Kabayama e Trabasso, 1999). According to (Lee, 1986), robotics vision is defined as the extraction process, characterization and interpretation of the information from three-dimensional images of world.

The automation systems are in great demand mainly for exploration in hostile, inaccessible environment. The mental stress associated with difficult tasks to certain operations, are challenges that can be reduced with the effective automation, (Naylor, 2007). The use of computational vision associated to the automation, possibilities offering to the operator appropriate and efficient resources so that repetitive tasks could be executed with much more speed and precision, even so not eliminating the human operator on functions, but trying to provide reduction of costs and better use of time, (Rudek, 2001).

The vision system can be applied in several applications. Nowadays there are aerospace applications and one of them is presented in this paper. It is proposed a vision system to detect sceneries changes in space vehicles platforms.

In Brazil, the integration of the parts that form the Satellite Launch Vehicle (VLS) is executed in specialized dependences of the launching center to allow the execution of tests related mainly with the phase of pre-launch of that vehicle, (Palmério, 2002). That integration is executed through a specialized unit denominated by Integration Mobile Tower (TMI). There are platforms of work installed inside the TMI. To monitor these platforms a vision system using artificial vision techniques and automation resources is proposed. By using images captured by cameras (images called sceneries) those can be analyzed and verified if there is some alteration indicating possible anomalies in the environment around the space vehicle. It is done by using cameras, image acquisition board, computer and specific developed software. The computational system was implemented using LABVIEW^{TM} .

2. SPACE VEHICLES PLATFORMS

The integration of the stages that form the Brazilian Satellite Launch Vehicle and pre-launch tests are executed at CLA (Alcantara Launch Center) in Maranhão, Brazil. There is a specified place to these activities, the called Integration Mobile Tower (TMI), Fig. 1.

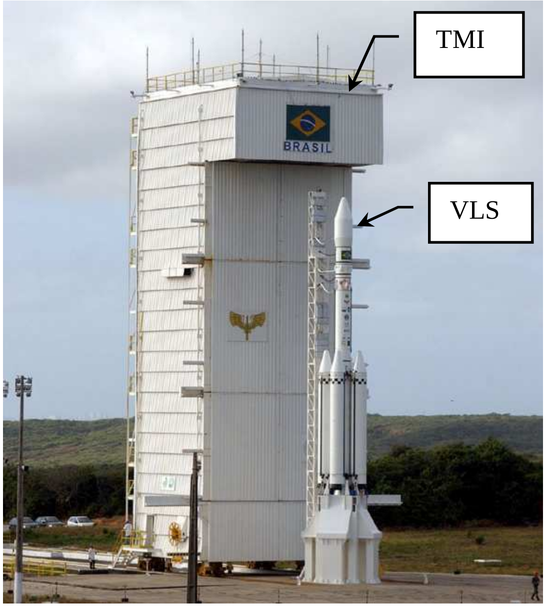

Figure 1 – VLS/TMI

That tower is sustained by metallic structure that has form of rectangular block, with larger side in the vertical, equipped with subsystem of horizontal movement on rails, Fig. 2. In that structure strategic points are foreseen for the installation of a rolling bridge, elevator, work platforms (fixed and mobile), doors and other necessary subsystems to assist the activities related with the integration task, tests and launch of that vehicle, (Yamanaka, 2006).

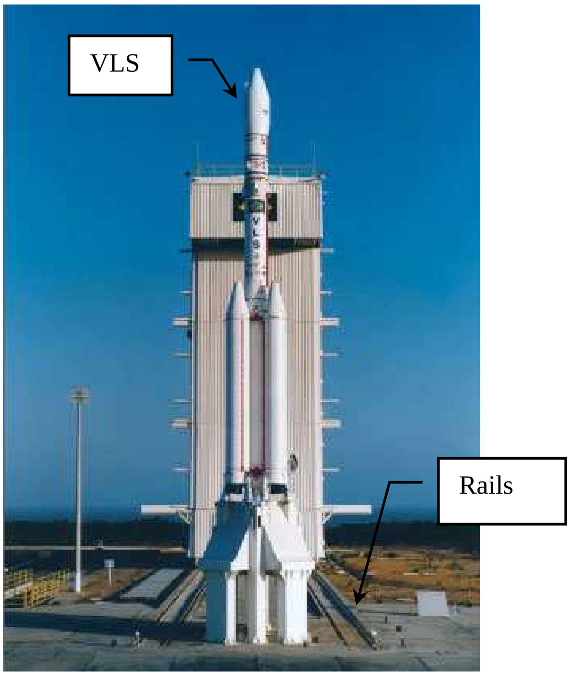

Figure 2 – Frontal View VLS.

The fixed and mobile platforms used by the operators in the execution of tasks related with the integration of the vehicle are installed in preset levels inside the tower, Fig. 3, on which several equipments are disposed.

During the tests of the launch vehicle, these mobile platforms are moved remotely, and the operator needs to verify if there is any object or people on these platforms before to order the moves. The operator has to go to the levels of those platforms, to execute a visual inspection of the area and verify if the conditions are adjusted to make the necessary movements, verifying for example, the presence of people or equipments on the platform. In many situations in executing that inspection the rocket is prepared to be launch, what means a situation that demands specific cares in order to minimize risks to the operator's physical integrity and material losses.

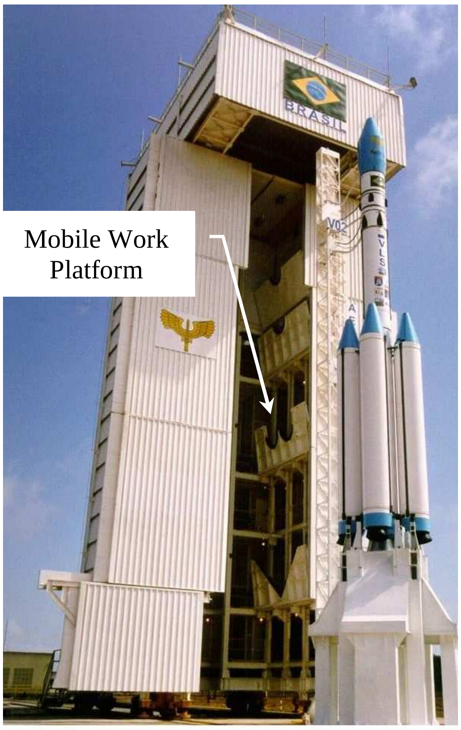

Figure 3 - TMI Partial View

3. VISION SYSTEM PROPOSED

Among the several applications of artificial vision for detection of scenery change, an application in the space area is selected: detection of scenery change in Platform of Integration of Space Vehicles, (Barbosa, 2008).

From the definition of standard scenery to be considered as a reference indicated by the operator, the task of detection of scenery change can be made in an automated way, intending to use a remote system to supervise defined areas, based on open architecture that uses computer science resources and artificial vision. The architecture proposal environment for this system is composed of hardware elements and software. The hardware components consist of computational equipments and cameras CCD to be installed inside the Integration Mobile Tower (TMI) positioned strategically for the observation of the environment defined by the fixed and mobile platforms, in all the levels. In that system the images are transmitted remotely to a computational system installed in a server. That vision system should facilitate, by implementing a dedicated algorithm using specific mathematical resources for the application, the detection of changes in the scenery and the registration of these different images. That occurrence will be signaled visually to the operator and a sequence of those images will be registered in electronic file with information about date and hour of its occurrence.

The installation of cameras in strategic points of the mentioned tower makes possible the constant observation of the environment defined by its mobile and fixed platforms. The comparison of the captured images, through the implementing of specific software, is a resource that allows the recognition of possible irregularities that can happen during the period of activities in the platforms.

In order to validate the application a representative prototype of the Integration Mobile Tower is used, with a space vehicle in its interior, and an artificial vision system.

An algorithm denominated "CompCena" is implemented, and its analytic flowchart is represented in Fig. 4. "CompCena" uses techniques of Artificial Vision for Detection of Change of Sceneries based on spatial filters, especially convolution for average filter. The routine that executes the comparison of the images, foresee the implementation of those techniques to avoid detections of scenery changes considered worthless by human vision.

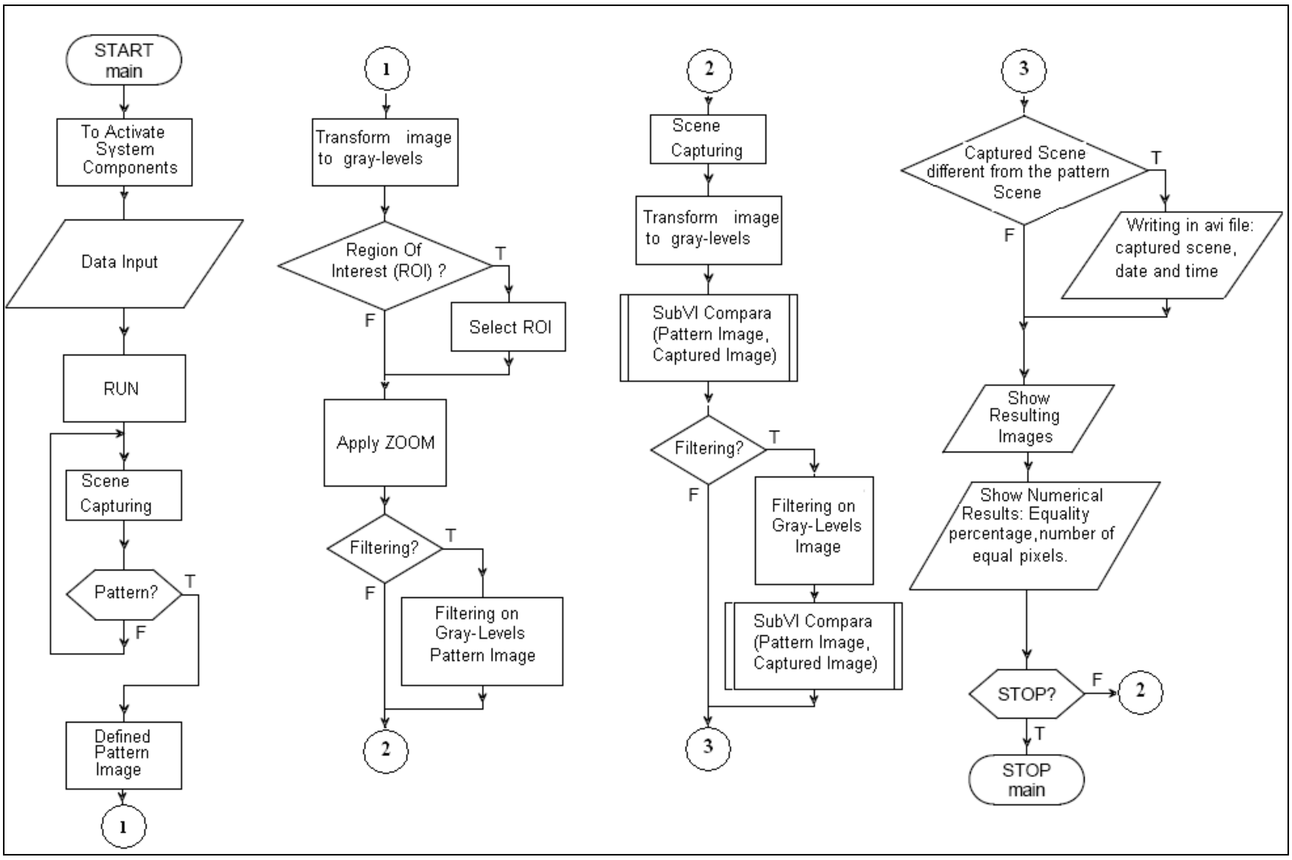

Figure 4 - CompCena Analytic Flowchart.

3.1. "CompCena" System

The system "CompCena.vi" was developed and implemented using LabVIEW^{TM} and IMAQ vision module resources. The system can be divided in two phases:

I. Capture of scenes for definition of the standard scene, and

II. Comparison of the captured scenes.

In the first phase, the application "CompCena.vi" is executed in LabVIEW^{TM} platform, the input data are supplied, and then the continuous scenes capture starts. By clicking a specific button, the operator defines the standard scene.

From the standard scene definition, the second phase has beginning, that is, the comparison with the scenes to be captured, Fig. 5.

Through bibliographical research, it was possible to conclude that among the image processing techniques the background subtraction is the most indicated operation to be applied in comparing scenes. The algorithm uses matrixes, transforming colored images to gray-levels and then to numerical matrix with the respective pixels values.

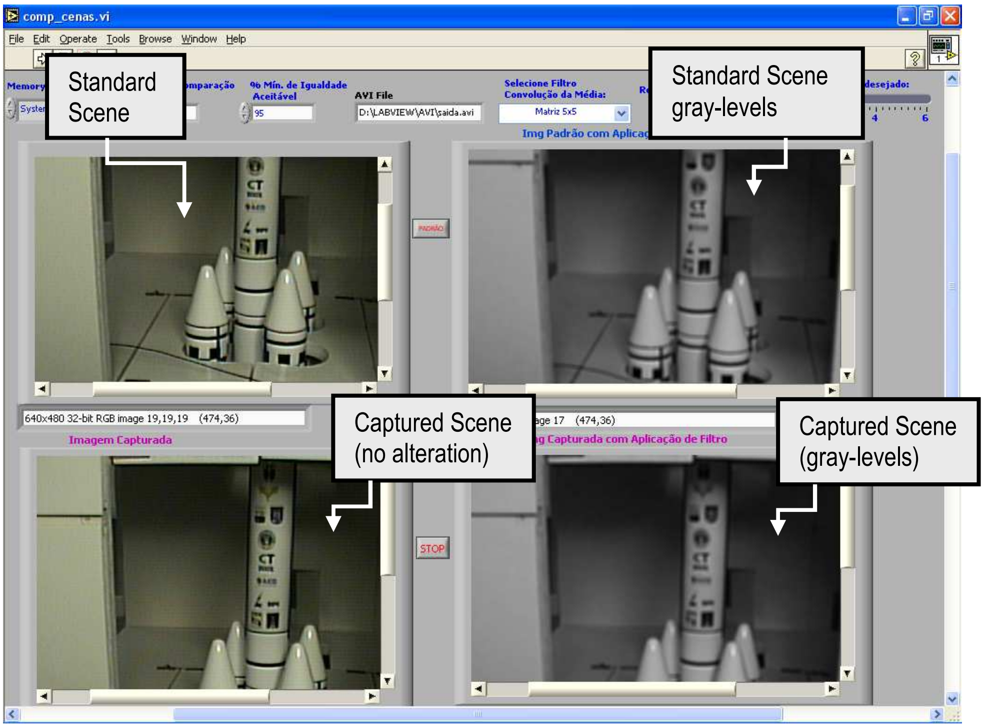

Figure 5 – Practical Test – Standard Scene, Captured Scene.

To decrease those alterations it was necessary to apply techniques to detect only the differences considered significant by human vision, for example, the presence of a strange object at the standard scene, Fig. 6. It was implemented a digital filter application algorithm, more specifically the spatial convolution average filter, and some others options were included in the algorithm, such as tolerances and minimum percentage of acceptable equality.

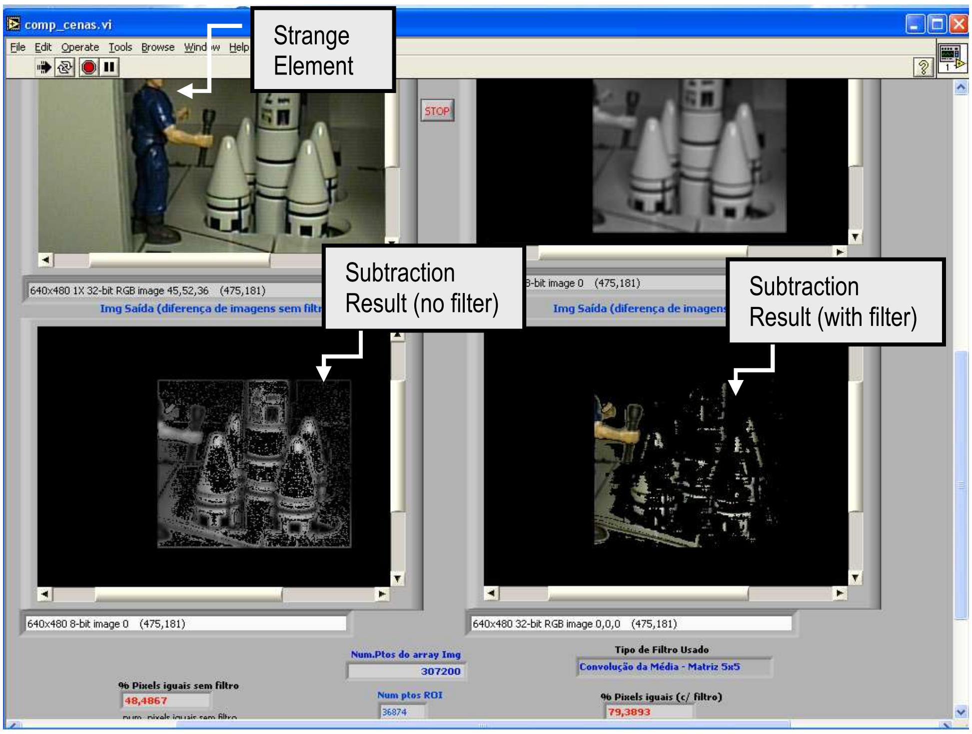

Figure 6 – Presence of a Strange Element - Image Subtraction Results

Convolution is a linear operator. It involves the construction of an output image by computing each pixel as a weighted sum of a local region of the input image with a fixed array or "convolution mask". The process is mathematically equivalent to many physical processes which occur during image formation, particularly optical blurring, though it is also useful for a variety of tasks including noise filtering. The matrices can have different sizes depending on the filter or the settings for a filter. According to (Traina, 2000), the image that indicates the weights for the convolution usually possesses small and odd dimension (3, 5, 7 or 9). The larger the matrix, the more pixels have to be read for every operation and the slower the filter will get.

Besides the filter applying an option to define a tolerance value to be considered in comparing pixels was also included. The operator defines this tolerance value to be used when subtracting images is done pixel by pixel. If the result of the subtraction is smaller or equal that tolerance value, the pixels would be considered equal.

In case of detecting difference in scenery, the system indicates to the operator through images and numerically. According to a value defined by the operator indicating an equality minimum percentage acceptable the system records in an electronic file this different image and information about date and time of its occurrence. This electronic file can be analyzed later on.

4. TESTS

In order to validate this application a representative prototype of the Integration Mobile Tower is used, with a space vehicle in its interior, and an artificial vision system. This prototype architecture uses only one camera positioned outside the tower, with the aim of monitoring the environment defined by the platform that aids the integration of the mentioned vehicle.

Through practical tests, comparisons were made with the obtained results of the difference of the images with and without filter use, analyzing the application of the masks from matrix 3x3 up to 9x9. For each case it was considered the variation of tolerance for pixels comparison between 0 and 5. In that way by executing practical tests and then observing the results at Tab. 1 and 2, the conclusion is that the convolution of the average using mask 3x3 would be enough to assist to the objective of the work. However, in the developed application, CompCena.vi, the possibility of the definition of Kernel is foreseen from matrices 3x3 or larger, until the maximum 9x9.

The Tab. 1 shows the results of that comparison not considering the scenery alteration, that is to say, to the perception of the human eye, two equal images, standard image and captured image. The resolution of the considered images is 640 x 480 pixels. In that table the differences on results with and without filter application for each applied mask can be observed.

Table 1 - Comparative of Experimental Results – Sceneries with no Changes.

MINIMUM PERCENTAGE OF ACCEPTABLE EQUALITY = **95%**												
Tolerance Value for Pixels Comparing	**0**		**1**		**2**		**3**		**4**		**5**	
	Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage	
Mask Used	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter
3 X 3	12,929	25,815	36,422	66,795	47,131	85,054	72,551	97,230	83,115	99,491	89,235	99,939
5 X 5	12,180	35,679	34,621	82,326	56,280	97,443	61,817	99,485	78,681	99,909	90,558	100
7 X 7	13,014	43,460	30,038	88,511	47,396	98,660	66,802	99,905	74,508	99,999	90,462	100
9 X 9	11,935	49,254	33,322	94,961	47,261	99,724	65,154	99,999	73,810	100	79,04	100

The Tab. 2 follows the same approaches for comparison that the Tab. 1, with relationship to the variation of the masks and of the tolerance for comparison of the pixels, but it presents the obtained results considering a scenery alteration.

Table 2 – Comparative of Experimental Results – Sceneries with Changes.

MINIMUM PERCENTAGE OF ACCEPTABLE EQUALITY = **95%**												
Tolerance Value for Pixels Comparing	**0**		**1**		**2**		**3**		**4**		**5**	
	Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage		Equality Percentage	
Mask Used	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter	No Filter	With Filter
3 X 3	8,279	10,854	31,991	54,580	46,287	71,316	62,011	83,048	72,004	86,938	78,396	88,579
5 X 5	9,302	25,834	30,044	67,691	47,214	81,460	59,721	85,980	65,991	87,493	74,341	88,794
7 X 7	11,366	32,330	29,736	72,060	45,715	83,290	58,764	85,918	65,730	87,879	72,844	88,968
9 X 9	10,306	18,847	28,634	74,926	48,902	83,547	56,969	86,072	65,319	87,759	70,779	89,013

According to practical tests executed it was verified that the obtained results when applied convolution of the average with Mask 3x3, is considered satisfactory for that application. That realizes a system with time processing adequate to the application, not impairing the final result presented in application, which is exhibited keeping the original colors of the pixels different from the standard image, Fig. 7.

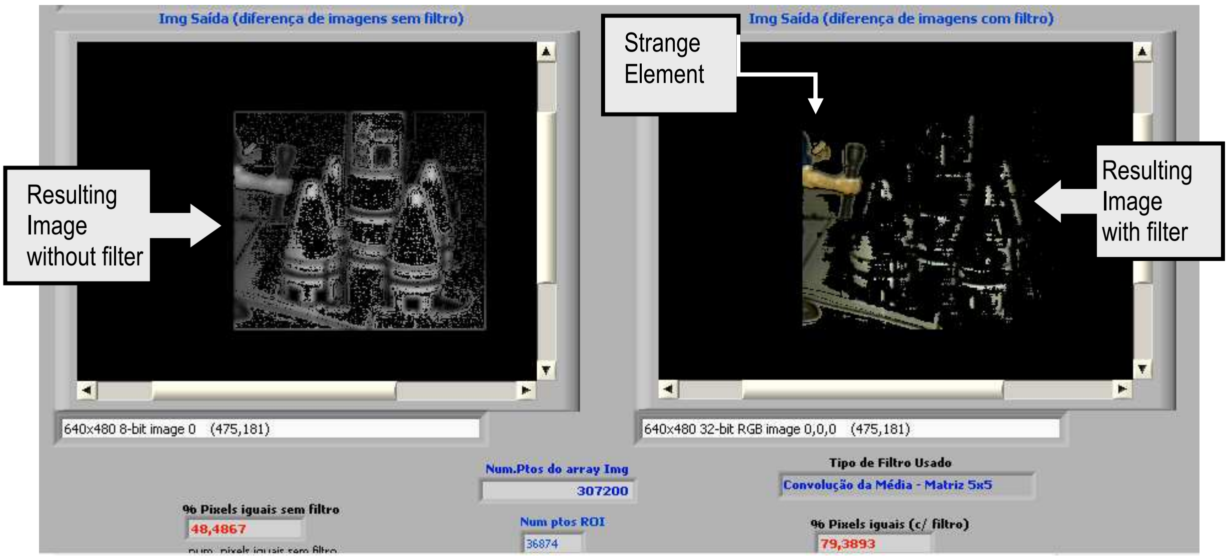

Figure 7 – Resulting Images

3. CONCLUSION

This work proposes system architecture to detect changing sceneries through successive compare images, implementing an algorithm using image processing techniques based on spatial filter, more specifically convolution for average filter.

All the manipulation and analysis images process is done implementing specific software with images captured by camera as input. The main goal of the execution of practical tests was to prove the algorithm effectiveness by comparing the results obtained from the difference between images with and without filter applied, and analyzing the application of the several masks varying from matrices 3x3 up to 9x9. The difference of the results according to the tolerance value defined was observed too. The obtained results using mask 3x3 are considered satisfactory. It means a system with processing time adequate to the application.

The fact of that research work to present a system of open and flexible architecture facilitates future alterations and/or inserts of procedures, seeking to offer as contribution the use of techniques of image processing integrated with automation resources in space application.

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