APPLICATION OF COMPUTER VISION IN SECURITY AND EMERGENCY ACTIONS

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Abstract

There is a wide area of possible emergencies, from intentional to accidental. Mobile robots can be used in lot of them. To use mobile robots, we must have both reliable and high quality computer vision. This paper deals with different aspects of robot/computer vision applications in emergencies. Since there are a lot of difficulties in outdoor applications of robots, human expertise, human experience and human reactions can be non-replaceable. The best way to overcome problems is to implement the system with human operator in the command loop. It is called teleoperation. When medical task have to be performed, teleoperation is the only choice for now, because of complexity of actions. If the medical operation (surgery) need to be performed, then it is called telesurgery. To help doctors to be more sensitive of the distant scene, virtual reality can be used and development of tactile sensors can be vital. In the paper, a novel edge detector is presented. It is the intention to use it in mobile robots constructed for emergencies. Depending on which standard algorithm is used the performance of edge detector is improved by 10.41% to 53.36%. This is only a small step in image processing necessary for reactions in emergency situations. Edge detection is used to form matrix of distances between edges in image and robot. The use is in force feedback by visual input. Another possible application is in face recognition. If edges are better recognized, characteristic lines are to be better identified and, finally, face recognition more successful. Face recognition is very important in safety applications, but also in human-robot interaction. The last subject included in the paper is wavelet prediction of the motions in the robot teleoperation.

Introduction

In the world of increasing interconnectivity and great dependences, any misuse of high tech or new materials can result in catastrophe. Usual emergency situations are: traffic accidents, fires, terrorism, environment pollution, war, earthquakes, volcano eruptions, flood, dryness, etc. Usually taken actions are: medical intervention, fire distinguishing (or control), ruins management, search and rescue in ruins, fire locations, marine accidents' locations, traffic accidents' locations, etc. Causes of disasters can be natural, but also the product of human

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actions (i.e. terrorism or negligence). These disasters can be monitored over telemonitoring or surveillance systems. Of course, that implies some sort of computer vision (Arsenio, 2003).

Computer vision applications can be used in teleoperation (Şendur and Guleryuz, 2004) over communication media (cable, wireless, etc.). It is very interesting when people cannot be in contaminated area (i.e. radiation, biological or chemical agents). Robots can be deployed in that area and human operator can command over visual tele-control (Seelinger, 2002; Slawinski, 2006). Robots can be programmed to distinguish fires, to search for survivors, to monitor contamination, etc.

This paper presents vision application in robot control for emergencies based on Internet and wireless link. Visual control loop is explained. Various image processing algorithms can be applied. Vital importance of edge detection in measurements is pointed out. It is a step toward advanced algorithms, such as motion estimation, intention recognition, decision making, object recognition, etc.

Edge detection can be used also in face recognition. It is interesting in security (i.e. to recognize authorized personal). Edge detection is vital in obstacle avoidance and object recognition. If robot recognizes humanoid shape, it can begin rescuing operations. Well recognized edges are also preferred for input to virtual reality controls.

The National Science Foundation (NSF) is an independent federal agency that supports fundamental research and education across all fields of science and engineering, with an annual budget of nearly $5.3 billion. Some of the project financed is development of search and rescue robots, such as in Figure 1.

***Figure 1:** Example of search and rescue robot (NSF PR 03-91, downloaded from http://www.nsf.gov/od/lpa/news/03/pr0391.htm)*

Figure 2 shows some of robots practical for experiments for all aspects of robot vision except stereo vision and telemedicine.


***Figure 2:** Some of available robots for presented research*

Figure 3 shows an example of tactile sensors for teleoperation (Genta and Antoniette, 2005; Çavuşoğlu et al., 2001). This can be used in telesurgery as in the other applications, including many sorts of virtual reality. Idea of telesurgery is illustrated in Figure 4.

Figure 3: *Example of tactile device for telesurgery*

Although many people form medical profession opposes the idea of replacing a real human doctor with any kind of robotic or telemedicine system, telesurgery is the matter of presence and close future.

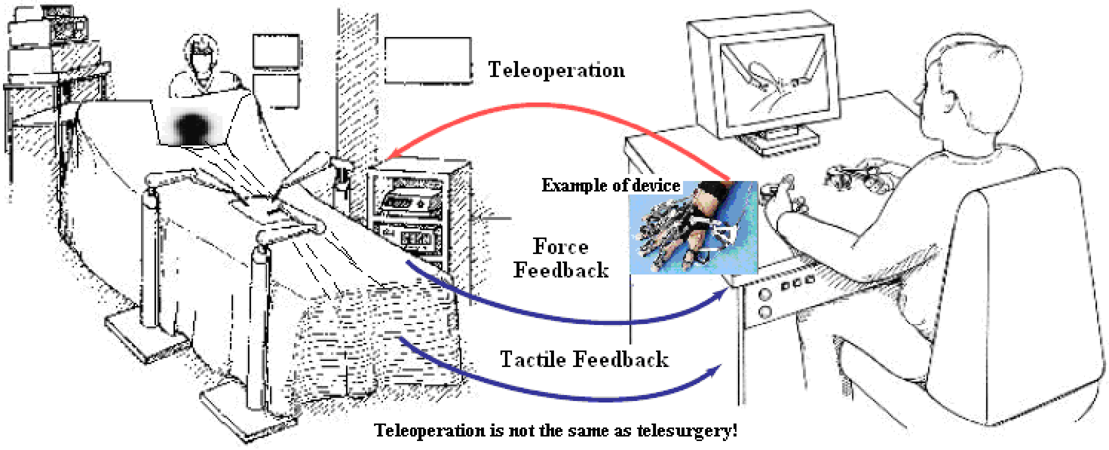
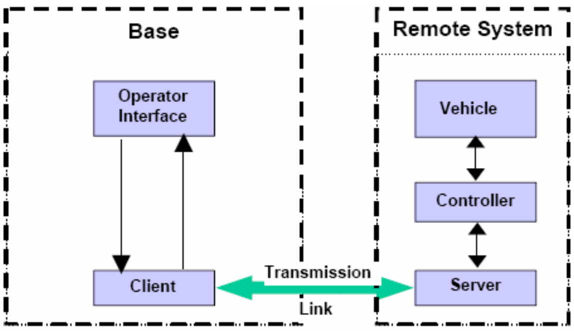


Figure 4: *Telesurgery*

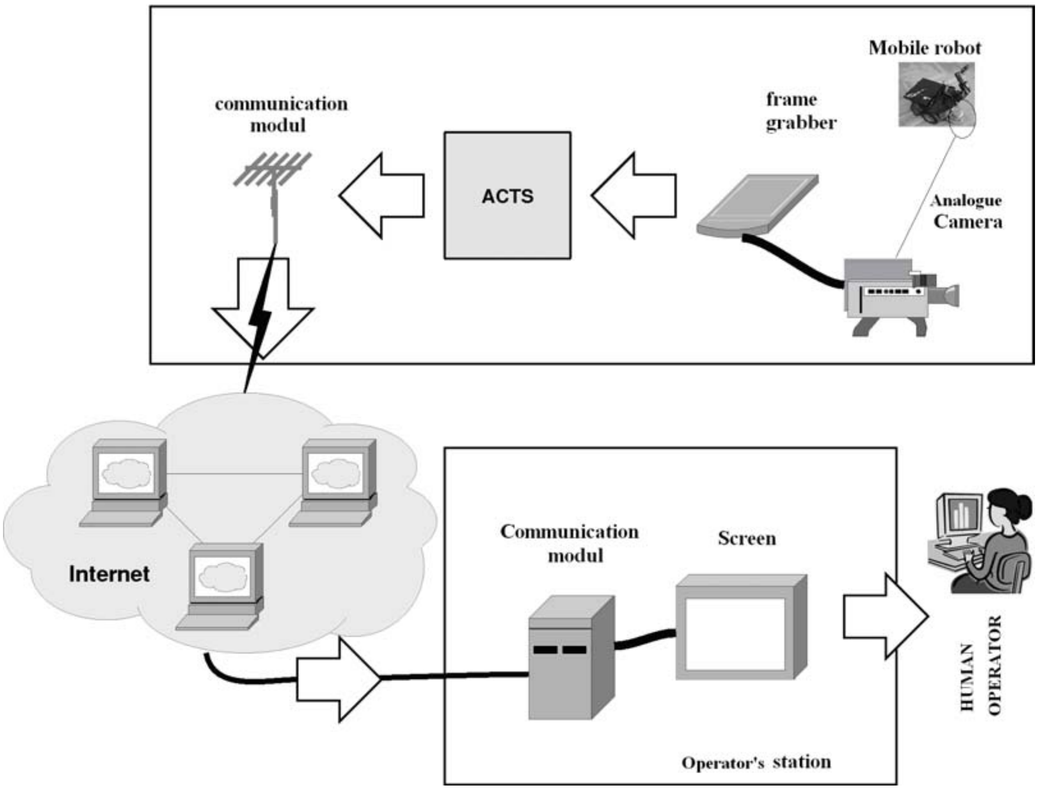
Theory and Method

Edge detection is a common low level step of image processing (Nixon and Aguado, 2002) for robot vision applications. An edge in an image is a contour across which the brightness of the image changes abruptly. It is often interpreted as singularities. Singularities can be characterized easily as discontinuities where the gradient approaches infinity. In discrete signal analysis edges are the local maxima of the gradient.

Figure 5.a illustrates basic structure of the teleoperation of robot. Place of the teleoperator is in the base, on safety, while the robot is in the dangerous environment. The modifications for improvement of robot's vision system are placed in the client's side of the system. As a matter of fact, this presents a simulation of a real situation and therefore it is experimental information flow.



a)



b)

Figure 5: *a) Basic structure of teleoperation, b) experimental setup*

Figure 5.b shows experimental setup from previous works, i.e. in (Budišić, 2006). Part which deals with the aim of this article is between communication and screen modules in client's application (operator's station).

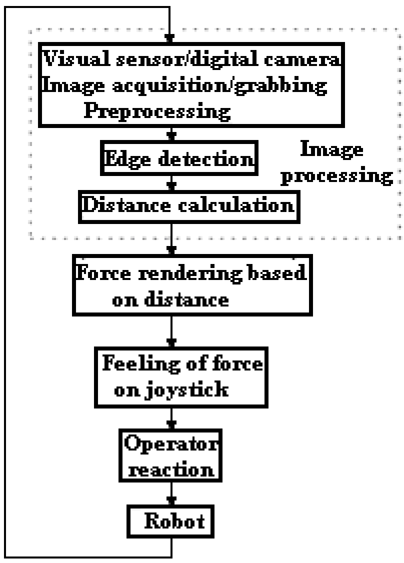


Figure 6: *Visual force feedback robot control*

Figure 6 shows a role of edge detection in force rendering in teleoperation. Based on distances from the edges, force is produces. The goal is that operator feels the force in proportion with the distance: if the robot is closer to the edge, the force that operator feels is higher. Feel of force is on the joystick, which operator uses for control of distant robot. For analogue cameras, installation of frame grabber is necessary to enable A/D conversation.

Most of the nowadays digital cameras do not need frame grabber. Figure 7 shows the role of edge detection in computer vision system for face recognition.

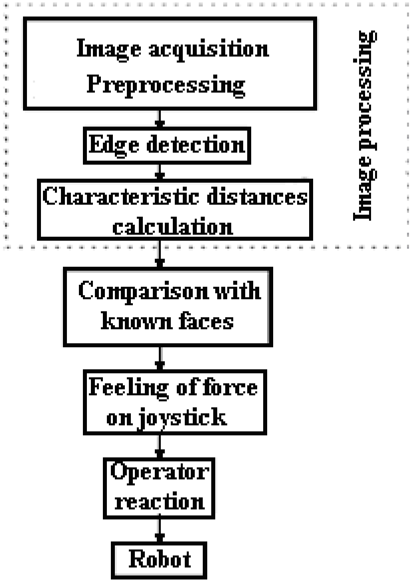


Figure 7: *Edge detection's role in face recognition*

Teleoperation has a lot of badly solved or un-solved problems and therefore teleoperation system needs improvements to be completely reliable. One of the problems is the problem of lost pockets of data. In force feedback based on visual data, the lost pockets of data are frames or parts of frames. Figure 8 is schematic explanation of the solution for the problem. Wavelet estimator estimates the value of pixels in the next frame based on wavelet regression (values of pixels in previous frames). If the next frame (time t + sampling interval, which is new present frame) does not come to the client side of communication channel on time, estimated frame is visible on the operator's screen. If the next frame comes on time, predicted frame is just overwritten with true frame (Casavola et al., 2006).

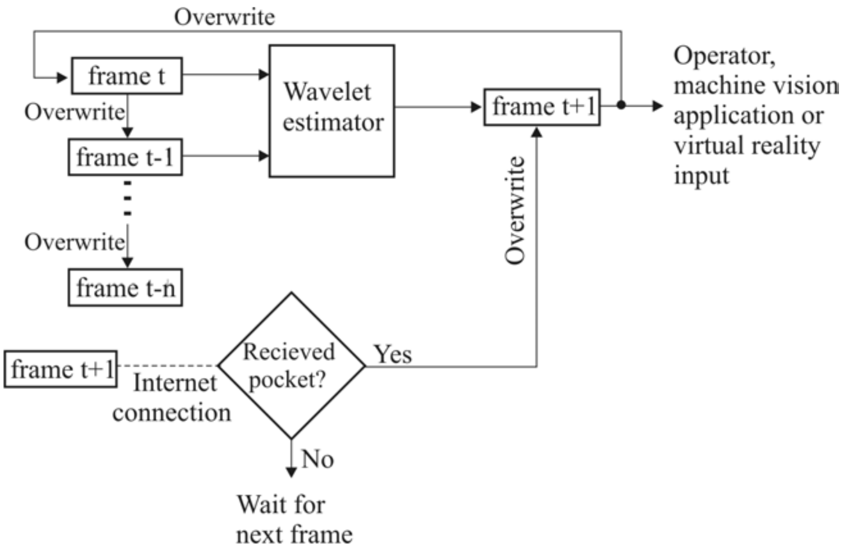


Figure 8: *Wavelet prediction in teleoperation*

We will now concentrate on necessary theory for these applications. Let us consider an image sequence $I(p_i, t)$ with $p_i = (x_i, y_i) \in \Omega$ the location of each pixel in the image. The brightness constancy assumption states that the image brightness $I(p_i, t+1)$ is a simple deformation of the image at time t:

$$I(p_i, t) = I(p_i + v(p_i), t + 1) \quad (1)$$

where $v(p_i, t) = (u, v)$ is the optical flow between $I(p_i, t)$ and $I(p_i, t+1)$. This velocity field can be globally modeled as a coarse-to-fine 2D wavelet series expansion from scale L to l (Bruno and Pellerin, 2002):

$$V_\theta(p_i) = \sum_{k_1,k_2=0}^{2^L-1} c_{L,k_1,k_2} \Phi_{L,k_1,k_2}(p_i) +$$

$$+\sum_{j\geq L}^{l} \sum_{k_1,k_2=0}^{2^j-1} \left[d^H_{n,k_1,k_2} \Psi^H_{j,k_1,k_2}(p_i) + d^V_{n,k_1,k_2} \Psi^V_{j,k_1,k_2}(p_i) + d^D_{n,k_1,k_2} \Psi^D_{j,k_1,k_2}(p_i) \right] \quad (2)$$

where Φ_{L,k_1,k_2} (p_i) is the 2D scaling function at scale L and Ψ^H_{j,k_1,k_2}, Ψ^V_{j,k_1,k_2}, Ψ^D_{j,k_1,k_2} are wavelet functions which represent horizontal, diagonal and vertical directions. These functions are dilated by 2^j and shifted by k_1 and k_2. The solution can be found by usage of chosen error function and minimization, e.g. (Bruno and Pellerin, 2002; Bruno and Pellerin, 2001):

$$E = \sum_{p_i\in\Omega} \rho\big(I(p_i + V(p_i,t), t+1) - I(p_i,t), \sigma\big) = \sum_{p_i\in\Omega} \rho\big(r(p_i + V), \sigma\big) \quad (3)$$

and the motion wavelet coefficient vector, θ, is calculated by:

$$\theta = \arg\min_\theta (E) \quad (4)$$

Once motion wavelet coefficients have been estimated for each frame f_i of a sequence S containing M frames, anyone can obtain a feature space spanned by the motion feature vectors θ_i, $i = 1, \ldots M$. To temporally segment the feature spaces Ω_{seg} (spanned by θ_{seg}), in (Bruno and Pellerin, 2002) a hierarchical classification with a temporal connexity constraint is considered.

Edge detection and wavelet prediction are based on above theory and well-known wavelet theory (Sweldens, 1998; Jansen and Oonincx, 2005; Mallat, 1999; Mertins, 1999). Motion between neighboring wavelet coefficients in all directions is used to find edges. Motion field in aproximation coefficients is used for prediction.

Results

Experiment is performed at NEC notebook with mobile AMD Athlon XP-M 2600+ processor working at 1.67 [GHz]. The system has 480 [MB] RAM and the operating system is MS Windows XP with service pack 2. Application for programming and execution was Matlab 7.0. Edge detector code is programmed as Matlab m-script. Norton Antivirus is in the background (which slows down the computer).

Table 1 shows time of operation for above mentioned experimental setup. Different setup or different computer configuration can result in faster or slower execution of the algorithm, which we proposed. As it can be seen from the Table 2, execution time is improved even between the first and the second generation wavelets for 11,65% (Haar wavelet) to 17,8% (Daubechies wavelet of the second order). Table 3 shows execution time for Perwitt method. If measurement no.1 is excluded (it is not close to other results probably due to activation of hard disk at the moment of experiment) we obtain more realistic average (the last row in the table).

Table 1: *Execution time of various edge detectors.*

Edge detector	Time of execution
sobel	0.5 [s]
canny	0.922 [s]
perwit	0.48 [s]
zerocross	0,544 [s]
Roberts	0.51 [s]
proposed with LWT lazzy	0,43 [s]

Table 2: *Execution time of various wavelets in filter and lifting implementation.*

Proposed edge detector	Time of execution
DWT haar	0,635 [s]
LWT haar	0,561 [s]
LWT lazzy	0,43 [s]
DWT db2	0,657 [s]
LWT db2	0,54 [s]

Table 3: *Replicability of the experiment on m-scripts (un-optimized code) for Perwitt method*

No.	Time of execution
1	1.582 [s]
2	0.46 [s]
3	0.52 [s]
4	0.451 [s]
5	0.45 [s]
average	0.6926 [s]
average without extreme	0.47025 [s]

Table 4: *Replicability of the experiment on m-scripts (un-optimized code) for Canny method*

No.	Time of execution
1	0.931 [s]
2	1.542 [s]
3	0.881 [s]
4	0.922 [s]
5	0.871 [s]
6	0.881 [s]
7	0.911 [s]
8	0.871 [s]
average	0.97625 [s]
average without extreme	0.895 [s]

Table 4 shows the same for Canny edge detector, table 5 for zerocross method, Table 6 for Roberts edge detector. Tables 7 and 8 shows results of the proposed wavelet edge detector based with lifting realization of wavelet transform. As it can be seen from the all presented tables, depending on which standard algorithm is used the performance of edge detector is improved by 10.41% to 53.36%.

Table 5: *Replicability of the experiment on m-scripts (un-optimized code) for zerocross method*

No.	Time of execution
1	0.681 [s]
2	0.531 [s]
3	0.531 [s]
4	0.521 [s]
5	0.531 [s]
6	0.531 [s]
average	0.544 [s]
average without extreme	0.529 [s]

Table 6: *Replicability of the experiment on m-scripts (un-optimized code) for Roberts method*

No.	Time of execution
1	0.441 [s]
2	0.431 [s]
3	0.441 [s]
4	0.441 [s]
5	0.451 [s]
6	0.45 [s]
7	0.451 [s]
8	0.451 [s]
average	0.444 [s]

Table 7: *Replicability of the experiment on m-scripts (un-optimized code) for proposed wavelet method with lifted wavelet transform of lazzy wavelet*

No.	Time of execution
1	0.431 [s]
2	0.451 [s]
3	0.45 [s]
4	0.451 [s]
5	0.451 [s]
average	0.4468 [s]

Table 8: *Replicability of the experiment on m-scripts (un-optimized code) for proposed wavelet method with lifted wavelet transform of Haar wavelet*

No.	Time of execution
1	0.681 [s]
2	0.521 [s]
3	0.521 [s]
4	0.521 [s]
average	0.561 [s]

Table 9: *Replicability of the experiment for proposed method with LWT of db2 wavelet*

No.	Time of execution
1	0.541 [s]
2	0.541 [s]
3	0.54 [s]
4	0.531 [s]
average	0.53825 [s]

Table 10: *Replicability of the experiment on m-scripts (un-optimized code) for proposed wavelet method with discrete wavelet transform (FGW setting) of Haar wavelet*

No.	Time of execution
1	1.172 [s]
2	0.641 [s]
3	0.631 [s]
4	0.641 [s]
5	0.631[s]
6	0.631[s]
average	0.7245 [s]
average without extreme	0.635 [s]

Table 11: *Replicability of the experiment on m-scripts (un-optimized code) for proposed wavelet method with discrete wavelet transform (FGW setting) of db2 wavelet*

No.	Time of execution
1	0.651 [s]
2	0.651 [s]
3	0.661 [s]
4	0.661 [s]
5	0.661[s]
6	0.661[s]
average	0.657 [s]

Tables show how stable times of executions are for different algorithms. If the range between minimum and maximum time of execution is smaller, the algorithm is more stable.

Discussion

As it can be seen from the results section, WT algorithm has smaller deviation from the average. Further improvement can be achieved by optimization of the code. The main goal in further research should be obtaining as short as possible time of operation. It is important in order to obtain more fps (frames per second). The goal can be reached by programming in C programming language.

It is also important to point out that the proposed algorithm works with gray scales, while standard algorithm works only with black and white output. This could be advantage in more sophisticated applications, such as groping of lines with same colours into objects.

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