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REPLACEMENT OF MISSING VISUAL DATA POCKETS WITH PREDICTION IN VISUAL CONTROL OF ROBOTS

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ABSTRACT
In this article, teleoperation over Internet is considered. A significant problem in teleoperations occurs if data is lost or late. This can lead to the fatal error in command decisions made by operator. Since operator must decide based on data on the client side of the link, modifications presented here are on the client side of the teleoperation system. Visual data was of particular concern. Visual data can be lost in transmission over the Internet and operator can be confused or disable in making decision of robot movement. We proposed replacement of missing data with wavelet predicted image of future frame.
Keywords: wavelet prediction, motion field, teleoperation, visual control, robot

1. INTRODUCTION
A lot of systems are proposed for teleoperation over Internet. Some authors even adopted a mathematical method without explicit time. However, un-predictive nature of time delays over the Internet could be perhaps calculated only by deterministic chaos, which is not the scope of this paper. Haptic feedback is usually used as a supplementary cue to help the user understand the virtual environment. Advanced robot applications have not to be dependent on merely blind haptic sense. Vision can be implemented in system of one camera and laser scanner or two cameras. To adopt images into digital system, frame grabber must be used for analog camera or digital camera. Visual control of robots is presented in many works and it is a subject of finished and on-going researches i.e. in [1, 2].
There are a lot of efforts in the direction on both teleoperation and teleoperation via Internet [3 - 5]. In [6] a PC-based vision system that can be used to detect moving objects from a mobile robot is described. An image processing board equipped with an MPEG motion estimation processor calculates a sparse but robust optic flow in real-time. Similar is presented in [7]. In [8] it is presented a predictive strategy for teleoperating through communication channels with unknown and possibly unbounded time delay, a remotely located precompensated plant subject to input and state-related pointwise-in-time constraints.
In [9] teleoperation system has been implemented in order to enable two human operators to perform collaborative tasks on a remote site by guiding two mobile robots. Operators control the robots using joysticks and graphical interface which displays images forwarded from cameras mounted on both robots. Force feedback is used to provide additional haptic information about obstacles in paths of

robots. Teleoperation system uses ubiquitous and publicly available Internet connection to deliver control and feedback information.
As any system with different senses, there is a problem if senses are not synchronized. This can lead to the operator's confusion, i.e. if force feedback come on time and vision part has delays, which is very real situation.
Another great problem is loss of data packages. To prevent that TCP protocol can be used. However, in collaborative control or in implementation with a lot of users, it is not possible. Therefore, prediction and implementation in wavelet domain is necessary. We proposed introduction of wavelet motion field and interpolation of wavelet coefficients. Wavelet motion field implementation algorithm is proposed. Wavelet prediction is based on motion field in wavelet domain calculated in real-time acceptable for teleoperation over the Internet.

2. PROBLEM AND SOLUTION

Teleoperation system can be implemented with force-feedback control. Basic structure of teleoperating system is shown in Fig.1.

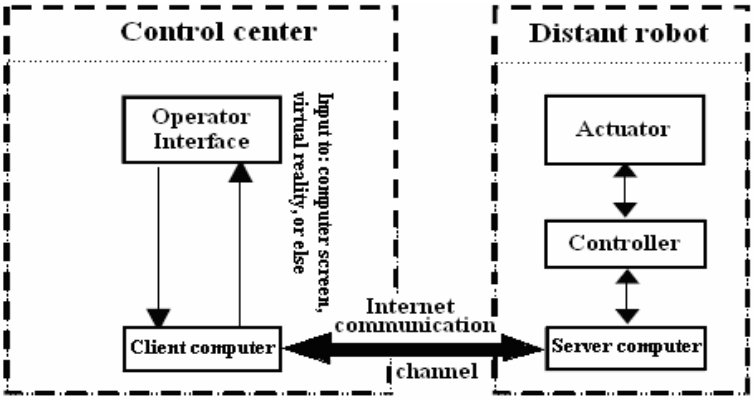

Figure 1. Basic structure of teleoperating system

Force feedback from visual data is considered in this article. Command algorithm is presented in Fig.2. as proposed for this application.

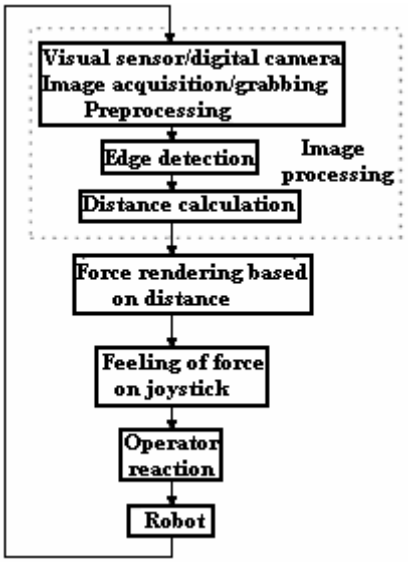

Figure 2. Basic structure of teleoperating system

In such a system, operator must see the distant scene in order to give correct commands to the robot. Robot's camera records the scene and server (attached to the robot) transmits frame sequences over the Internet to the client, which is used by operator. If there is only visual feedback control loop, loss of frame results in disability to perform operations correctly. The result can be material damage or, in the worst case, death of people in the distant scene. To avoid that unfortunately event, some sort of prediction must be used.

This paper deals with wavelet prediction of frames on the client computer. The goal is to simulate appearance of the next frame. In case when a frame is missing, predicted frame replaces the missing frame. This is also important in teleoperation with virtual reality over Internet, when a non-interrupted description of the distant environment is needed.

Till recently, it was not possible to use wavelet methods for fast on-line applications due to a large quantity of data needed for wavelets. Advance in computer technology enabled usage of wavelets, because of increased computer power.

We proposed an algorithm for visual control over Internet with inclusion of wavelets. Steps are: edge detection, calculation of distances, prediction of edge location in the next frame and calculation of distances from the predicted image (if new frame have not reached the client side of communication channel). Measurement of the distance can be performed by visual data [10 - 14].

Digital image and video processing play important role in many robot operations, such as obstacles avoidance, object recognition, measurement, etc [10, 14]. To enhance resolution of robot vision algorithms, it is possible to use superresolution algorithms. Superresolution problem includes motion estimation interesting in robotics.

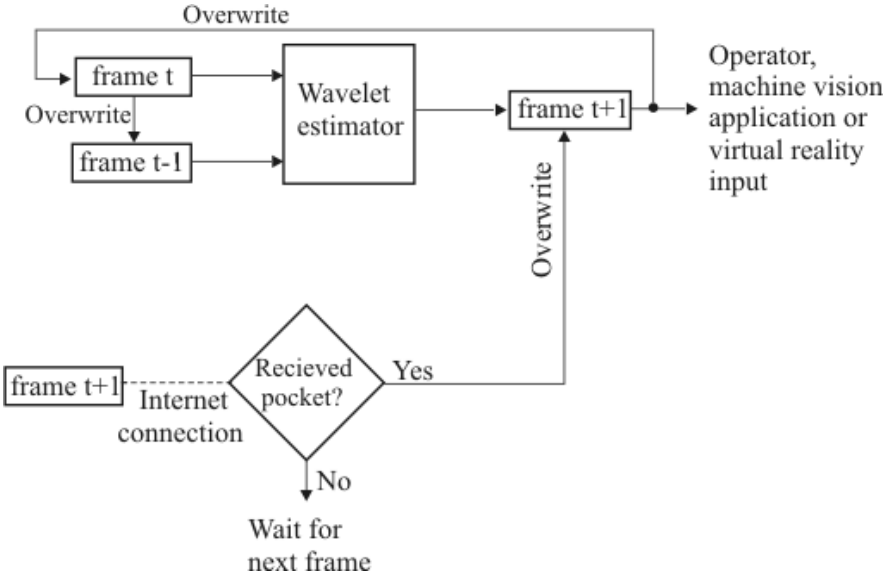

Figure 3. Proposed solution for advanced output (input to i.e virtual reality)

3. RESULTS

Experiments on client side are performed on mobile AMD Athlon XP-M 2600+ processor working at 1.67 GHz. The system has 512 MB RAM and the operating system is MS Windows XP with service pack 2. Application for programming and execution was Matlab 7.0, Image processing toolbox and Wavelet toolbox. Edge detector code is programmed as Matlab m-script. Standard windows processes (such as task manager, explorer, system tray; 40 in total including an antivirus application running in the background) are in normal working mode. This is important because if some of them are not present, execution speed can be increased.

The experiment deals with possibility of wavelet application for such purposes. It proved that wavelets can be used for real-time applications, such as robot vision and teleoperation.

Fig. 4. shows results for time execution of proposed algorithm. Resoultion in the experiment is 640x480. Diagram shows time of execution for frames in sequence. Some of frames are executed faster and some slower.

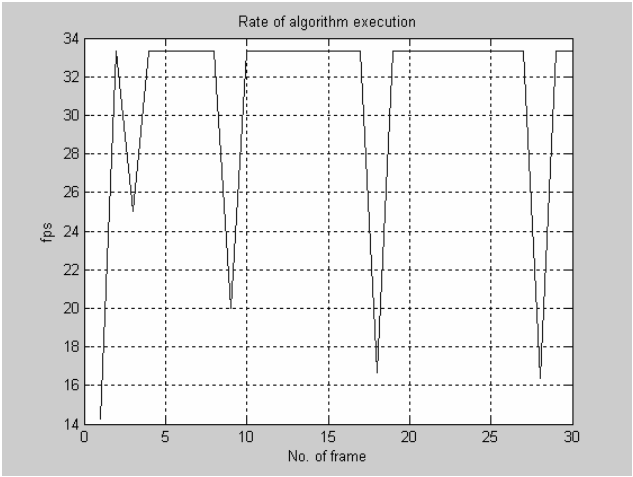

Figure 4. Execution time of wavelet motion field calculation in Matlab

4. CONCLUSIONS

The algorithm is performed with different speed at time. Minimums observed in Fig.4. can be smoothed by memory managment and hard disk control. The entire algorithm should perform faster if it is programmed in C++ programming environment, which is possible space for improvement in time of execution. Prediction, as here presented, is only used for one frame replacement – the frame which is missed in Internet trafic. For more deeper study and possible prediction of more than one frame, more previous frames should be considered.

5. REFERENCES

[1] Seelinger M., Yoder JD., Baumgartner ET, Skaar SB.: High-precision Visual Control of Mobile Manipulators, IEEE Transaction on Robotics and Automation, 18(6), pp. 957-965, 2002.,

[2] Saiki, J.: Feature Binding in Object-file Representations of Multiple Moving Items. Journal of Vision, 3(1), pp. 6-21, 2003.,

[3] Rajugopal, G. R.,. Hafez, R. H. M.: Adaptive Rate Controlled, Robust Video Communication Over Packet Wireless Networks, Mobile Networks and Applications, 3(1), pp. 33-47, 1998.,

[4] Genta, G., Antoniette, M.: Teleoperation Support for Early Human Planetary Missions. Annals of the New York Academy of Sciences. vol. 1065, pp. 271-279, 2005.,

[5] Slawinski, E., Mut, V., Postigo, J. F.: Teleoperation of Mobile Robots. Latin American Applied Research. 36 (2), pp. 79-86, 2006.

[6] Stöffler, N. O., Schnepf, Z.: An MPEG-Processor-based Robot Vision System for Real-Time Detection of Moving Objects by a Moving Observer. In Proceedings of 14th International Conference on Pattern Recognition, vol. 1, pp. 477, 1998.,

[7] Mitsumoto, S., Yuasa H., Heitou, Z.: Moving Object Detection from MPEG Coded Picture. Proceedings of IAPR Workshop on Machine Vision Applications NVA'98, Tokyo, Japan, pp. 422-425, 1998.,

[8] Casavola, A., Mosca, E., Papini, M.: Predictive Teleoperation of Constrained Dynamic Systems Via Internet-Like Channels. IEEE Transactions on Control Systems Technology. 14(4), pp. 206-16, 2006.,

[9] Budišić, M.: Visual Feedback in Mobile Robots Teleoperation. Master Thesis, University of Zagreb, Faculty of Electrical Engineering and Computer Sience. 2006.,

[10] Neal, B.; Russ, J. & Russ, J. C.: A Superresolution Approach to Perimeter Measurement. Journal of Computer-Assisted Measurement. 10(1), pp. 11-2., 1999

[11] Candocia, F. M.: A Unified Superresolution Approach for Optical and Synthetic Aperture Radar Images. PhD Thesis, University of Florida, 1998.,

[12] Nguyen, N. X.: Numerical Algorithms for Image Superresolution. PhD Thesis, Stanford University, 2000.,

[13] Vujović, I. & Kuzmanić, I.: Wavelet Quasi-Superresolution in Marine Applications. Proc. of the 48th ELMAR-2006 focused on Multimedia Signal Processing and Communications. Zadar, Croatia, 07-09 June 2006, pp. 65-68., 2006.,

[14] Vujović, Kezić, Kulenović, Kuzmanić, Force Feedback in Combined Haptic and Visual Interface for Teleoperation Systems, 4th Int. Conf. on Computer Aided Design and Manufacturing, 19th-23rd September 2006., Supetar, Croatia, pp 99-100, 2006.