Autonomous Input Management for Human Interaction-Oriented Systems Design

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***Abstract*—In this paper evaluation of a policy-based algorithm for video inputs switching is presented. The term 'data quality' is not trivial for Human-Machine Interaction systems, yet a simple and efficient algorithm is needed for choosing the most valuable video source. This becomes particularly important for systems that support functional decomposition of image processing algorithm, which are designed for non-optimal working environment. In this paper an autonomous input management system is proposed, which consists of a data quality evaluation algorithm and a simple decision algorithm.**

Keywords – Human-Machine Interaction (HMI), Machine Vision, Decision Systems, Distributed Systems, Autonomic Systems

I. Introduction

AN INCREASING number of computer and robotic systems designed for interaction with humans are using computer vision as its basic information source. Advances in vision– and sound-based interaction are fundamental for developing efficient and fluent interactions. The most recent implementations and research conducted have proven that it is possible to implement an ample vision– and speech-based man-machine interaction system, however the tests were run in a laboratory environments only. In real life applications the issue is much more challenging, especially in case, where various environments and conditions are taken into account.

However, there are some mechanisms in biology, which are able to handle both data acquisition and information processing in conditions exceeding the capabilities of the very acquisition subsystems. As an example – human can see in a dark room without the daylight, human can read and understand words even if the majority of letters are illegible.

Whilst the goal of the interaction is not only entertainment, computer systems and robots are also supposed to be able to support and to protect humans. To do that, these systems would have to contain a more efficient acquisition and information processing subsystems than humans. It is not difficult to find future applications for systems that expand the acquisition possibilities of human and interact using speech and/or vision: fire rescue teams support robotic systems, traffic collision and pedestrian avoidance systems, etc…

II. Policy-Based Input Switching

It is theoretically possible to implement all available acquisition systems and to process all the input information (vision, thermal video, night vision, etc…), but in real-life applications it is not efficient because the data streams are often too massive and require high computing power for real-time processing and inferring, so the implementation in an embedded system would be impossible. Transmission of multiple video streams to a remote workstation/server is also not always possible due to the limited bandwidth [1].

However, it is possible to choose one input at a time and transmit it (or process it locally) [2], if the system was able to judge the value of the data input quality of its acquisition subsystems. The quality evaluation could be performed on the basis of static threshold values (e.g. any measure of image noise or edges quality), but in that case it would be just a simple condition, with no deeper meaning.

The Policy-Based Input Switching (PIS) becomes especially useful when there is a necessity for adjusting/changing the policy for choosing an input depending on circumstances or environment. For example, the visual input of smoke has a relatively low level of noise and a satisfying brightness level, while the input is completely useless and should be switched to thermography (or at least infrared vision).

The proposed PIS conception is not just a set of rules and threshold values, but an entire framework offering wrapper functionality (similarly to [3], [4], [5]) for additional modularity and as a foundation for autonomous policy reloading/changing. A semi-autonomous mobile robot, with PIS implemented, designed for supporting a fire team, would be able to have its policy changed for operating in a particular environment and would be able to change its policy autonomously depending on any transient environment parameters (e.g. brightness, opacity, visibility, obstacles, temperature).

III. Subjective Quality Evaluation Procedure

The Subjective Quality Evaluation Procedure (SQEP) is implemented in the core of the PIS framework and its role is to decide locally on the active input (as a part of policy algorithm) and on the active policy (as a part of wrapper's autonomous module). Whilst the SQEP is intended to be run locally (e.g. on an embedded system), with as little processing involved as possible, it should be designed to involve only simple and efficient operations for evaluation of the data input.

In a pilot study implementation a basic policy was implemented for choosing the best visual data input out of three available inputs: (1) video stream (640x480 pixels, RGB 24bpp), (2) night vision (640x480 pixels, monochrome 8bpp), (3) thermography (simulated, 640x480 pixels, monochrome 8bpp). The exemplary SQEP was implemented to choose between (1) and (2) basing on brightness and noise and then between (1|2) and (3) basing on the width of histogram of (1|2). Fig. 1 shows an exemplary quality coefficient calculated for every frame of night vision video input and RGB video input. The data quality coefficient implemented in the test application is the distance of frame's histogram's maximum from the 'black-or-white' pixel's value. However, the data quality coefficient is not in the scope of this paper and it can be replaced with any kind of data.

Fig. 1 shows the value of a quality coefficient calculated for two different acquisition subsystems, acquiring visual information of the same scene and objects and in the same temporal context. Acquisition starts in darkness, and c.a. 128th frame a dim light source is turned on. The light is bright enough to turn off the infrared lighting, but not bright enough for the computer vision camera to acquire data of good quality. This is the case, in which it is highly beneficial to have a SQEP procedure implemented in the PIS system.

In a PIS system, the algorithm of a policy (and its rules or conditions, parameters and decisions) is intended to be easily replaceable, so that a policy could be changed at runtime, without any modifications to the inputs and outputs of PIS policy wrapper.

In the PIS system, the wrapper's functionality is extended to support autonomous policy exchange. Therefore, two-level modularity is considered:

- Input selection, within a single policy, with the use of SQEP,
- Policy selection - exchange of the strategy (and inputs' quality evaluation coefficients).

IV. SQEP for Autonomous Input Management

The main goal of using the proposed framework is to extend the functionality, versatility and robustness of the acquisition

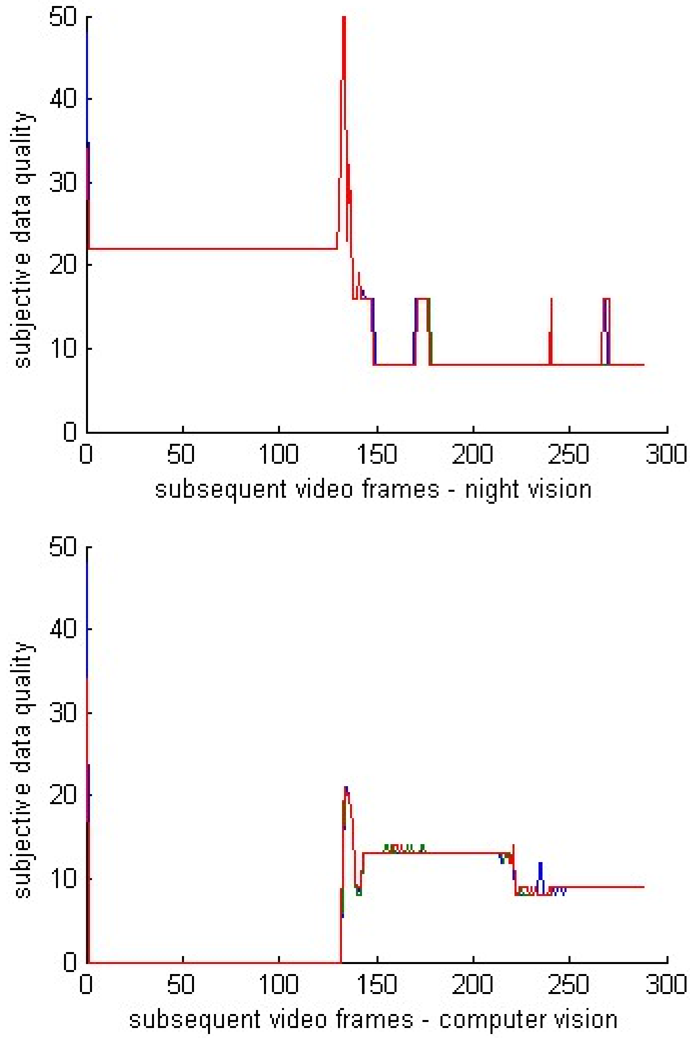

Fig. 1. Compartment of two acquisition subsystems, showing data quality during a change of lighting in the scene.

subsystems of vision-based mobile robots. This goal can be achieved only if the outputs of the Acquisition Subsystems (i.e. inputs of PIS system) and the outputs of PIS system (i.e. inputs of Cognitive/Decision System) will be developed/redesigned to become modular and replaceable. Therefore, the Subjective Quality Evaluation Procedure (SQEP) should:

- handle the evaluation of all inputs available in the hardware and all possible combinations (subsets) of these inputs,
- produce the same set of predefined output variables and data structures.

The SQEP should offer not only the possibility of on-demand input switching, but most of all it should perform the input selection procedures autonomously, if there is a better data quality input than the currently processed one. The decision about which input to process should be done locally to prevent transmitting of all data inputs to remote servers and the inputs should be evaluated in a simplest possible

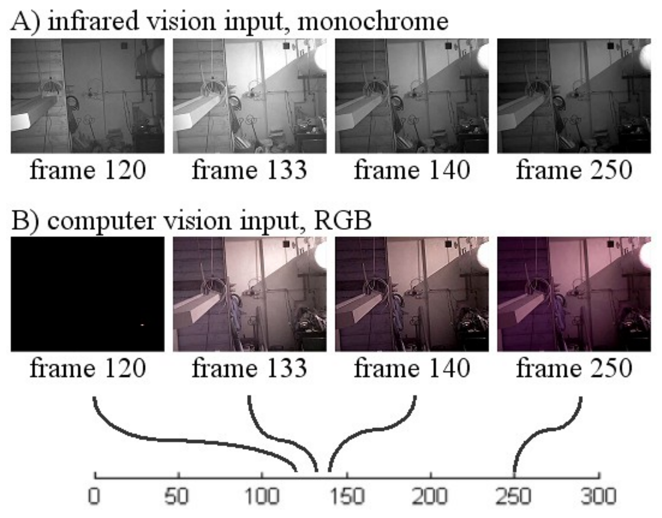

Fig. 2. The exemplary visual data input: darkness (frame 1..127) and with a dim light turned on (frame 128..288). Frames 128..140 are too bright due to the automatic white balance feature.

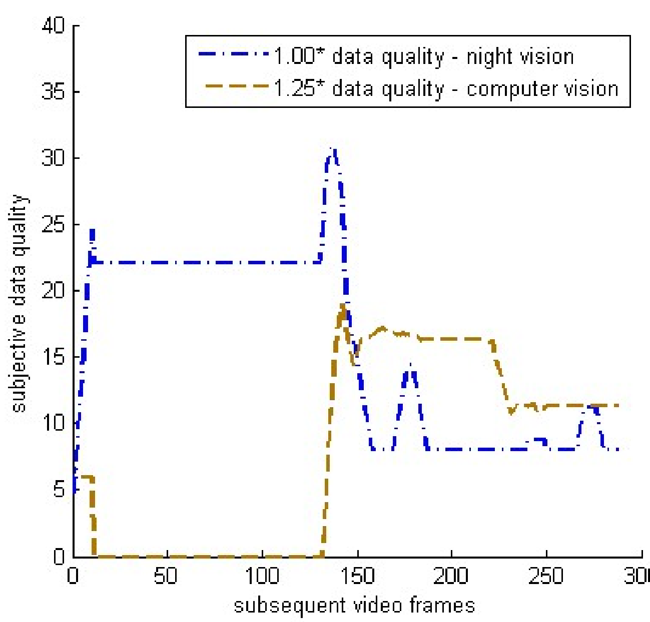

Fig. 3. An exemplary simple data quality coefficient for SQEP system for a policy-based input switching system, during a change of lighting in the scene.

way to save the CPU cycles of local/mobile/embedded system.

In the Fig. 4 three inputs are depicted. The current policy (inner dotted rectangle) evaluates the subjective quality of these inputs (three plots on the left side) and compares them (the plot with a frame) to choose the currently most valuable data input. The most important feature of SQEP is the capability of autonomous data quality evaluation and input switching. The most important benefits of using SQEP are:

- only one input is being transmitted to the Cognitive/Decision System at a time,

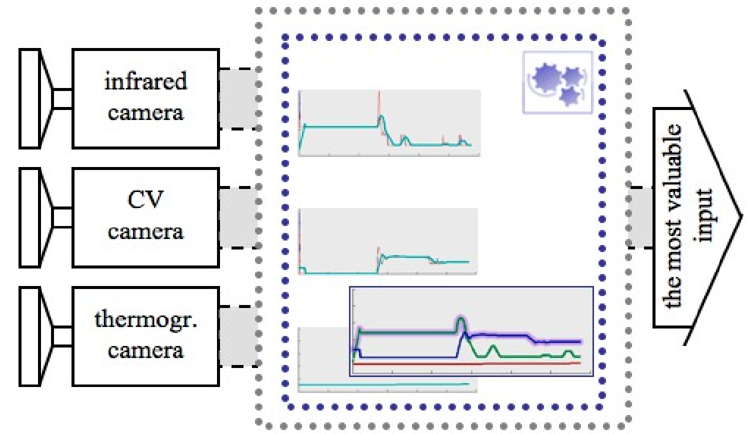

Fig. 4. The Policy-based Input Switching system's wrapper for automatic data input quality evaluation and selection. The policy (depicted as the dotted rectangle) can be replaced depending on circumstances and the working environment.

- the most valuable data input is connected to the Cognitive/Decision System at a time, and
- the coefficients and rules (the algorithm) of input quality evaluation (i.e. the policy) can be changed at runtime by PIS system.

V. PIS for Autonomous Policy Management

The SQEP has proven to be useful Ű it is beneficial in order to stay connected to a good data quality input, even in a changing environment. The basic PIS functionality Ű the possibility to change selection criterions (i.e. the policy) e.g. different environments is also a very attractive feature.

The most useful feature of PIS system, however, is the possibility to change the selection criteria in runtime (without rewriting the code, compiling, uploading, running). Thus there is no need to interrupt learning/execution or to reset the system's memory/knowledge/execution.

The PIS system, in its most sophisticated version is expected to be able to change its policy 'intentionally' (i.e. as a result of a high abstraction level decision of the Cognitive System). Although in some cases it is not 'harmful' for a mobile system (e.g. there is no need to stare at the Sun to see it's too bright), but sometimes it may be the crucial feature for the accomplishment of the horizontal goal of the system (e.g. the image quality of a burning house can be outstanding, while switching to a relatively poor thermo vision input would enable one to see that there are still people inside the building and thus save human life).

VI. Advantages for HMI Systems, Future Work

HMI systems are quick. Future work will involve implementation of inter alia virtual agents [6] and bio-signals (such as EEG or speech). Applications of virtual agents would make the system 'human friendly'. This could be cause by the skill of expressing emphatic emotions towards potential users and as a result would enhance human-machine interaction. As a result positive perception of the system could be improved. Initial tests, where the face mimic was implemented were conducted with the usage of the Emotiv EPOC headset [7].

As mentioned above, part of pre-testing was made using Emotiv EPOC headset, as a result the future work will involve development of a standalone application (AE), which would not need PC, but would enable to connect the Emotiv EPOC headset with any embedded platform. There would also be no MATLAB-based signal processing.

There are also plans to advance the work in the way, that various (not only EEG) bio-signals could be used in order to extend the possible application of the proposed solution. Bio-signals such as speech, eye-movements or EMG would be implemented [8].

The proposed control architecture should also be improved in order to reduce appearance of potential control errors, which is a common issue in autonomic systems [9].

REFERENCES

[1] M. Podpora, 'Task parallelization of image recognition procedures in a computer cluster', *IV SWD Conference Proceedings,* No. 335/2010, vol. 63, 2010, ISSN 1429-1533.

[2] M. Podpora, 'Dynamic re-definition of Region-of-Interest in Vision SystemŠs Feedback', *Proceedings of the 2nd International Students Conference on Electrodynamic and Mechatronics*, 2009, IEEE eXplore.

[3] M. Pelc, R. Anthony, 'Towards Policy-Based Self-Configuration of Embedded Systems', *System and Information Sciences Notes,* vol.2(1), 2007, pp. 20–26.

[4] M. Pelc, R. Anthony, A. Kawala-Janik, 'Context-Aware Autonomic Systems in Real-Time Applications: Performance Evaluation', *Proceedings of 5th ICPCA 2010,*, 2010, pp. 153–160.

[5] R. Anthony, M. Pelc, P. Ward, and J. Hawthorne, 'A Flexible and Robust Run-Time Configuration for Self-Managing Systems', *Proceedings of SASO 2008,*, 2008, pp. 491–492.

[6] M. Ochs, C. Pelachaud, D. Sadek, 'An Empathic Virtual Dialog Agent to Improve Human-Machine Interaction', *AAMAS '08 Proceedings of the 7th International Joint Conference on Autonomous Agents and Multiagent Systems,* vol. 1, 2008, pp. 89-96.

[7] http://www.emotiv.com

[8] F. Casacuberta, J. Civera, E. Cubel, A. Lagarda, G. Lapalme, E. Macklovitch, E. Vidal, 'Human Interaction for High-Quality Machine Translation', *Communications of the ACM – A View of Parallel Computing CACM Homepage archive,* vol. 52, 2009, pp. 135-138.

[9] P. Berg-Yuen, S. Mehta, E. Pasiliao, R. Murphey, 'Control of Human-Machine Interaction for Wide Area Search Munitions in the Presence of Target Uncertainty', *HRI '12 Proceedings of the seventh annual ACM/IEEE International Conference on Human-Robot Interaction,* 2012, pp. 195-196.