VOL. 10, NO. 10, JUNE 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

UAV REMOTE CONTROL DISTRACTION PREVENTION TROUGH SYNTHETIC AUGMENTED VIRTUAL IMAGING AND OCULUS RIFT-STYLE HEADSETS

Luca Piancastelli, Raimondo Alberto Bernabeo and Leonardo Frizziero
Department of Industrial Engineering, ALMA MATER STUDIORUM University of Bologna, viale Risorgimento, Bologna, Italy
E-Mail: leonardo.frizziero@unibo.it

ABSTRACT

A remote control station for Unmanned Aerial Vehicles (UAV) based on oculus Rift-style headsets and joysticks is proposed in this paper. With this solution situation awareness and distraction can be controlled and measured during the flight. With Virtual Augmented Reality (VAR) software it is possible reproduce accurately both the cockpit and the external view thanks to the helmet tracking system. Also the head-up display (HUD) and up-to-date flight instruments can be reproduced. In this way the PF (Pilot Flyng) station can be reduced to helmet, throttle/stick joysticks with force feedback and a few additional LCDs. Another main advantage of VAR headsets is the possibility of reconfiguring the cockpit via software and to use it for several different UAVs. In Figure-5 it is possible to see a logical schema of a VAR station: the pilot inputs via helmets (line of sight direction), flight controls (stick and throttle) and switches on joysticks the data in the AVCS software (Aircraft Visualization and Control System): The Aircraft Visualization and Control System take the data from the aerial vehicles, elaborates them and outputs the external view (external visual system) and the view of instruments (instrument visualization system). These two "images" are overlapped and mixed in a highly hierarchical visualization system, where only the relevant objects are depicted. To do so the external camera images from the aerial vehicle are analyzed and cleaned of all non-relevant data. The data from the sensors are also to be included in the synthesizing process. The application of these ideas as discussed in this paper consists of the realisation of a VAR display system for a remotely piloted aerial vehicle. All the instruments are modelled via Head Up Display (HUD) while the external scenery is analyzed and only relevant elements for mission accomplishment or collision avoidance are represented. The PF have the possibility of a 360° field of view. Sound realism and true situation awareness can be then achieved. Software for distraction control and situation awareness can be easily implemented in the system. A synthetic audio interrogation system can keep track of the current state of alert of the PF.

Keywords: UAV, remote control, augmented reality.

INTRODUCTION

Although flying a UAV seems remarkably similar to playing a video game, the consequences of every pilot's actions are deadly serious. Unmanned planes are at the forefront of gathering aerial data around the globe, so in addition to being a skilled operator, the pilot must be able to analyze data imagery in order to make snap decisions about when to pursue a lead or to continue the "mission". In long and tiring out of flight the Remote Flying Pilot (RFP) has to deal with several different situations inboard and outboard the aerial vehicle. Since modern UAV will fly along with general aviation aircraft, all the common duties of a normal pilot will be performed. Vehicle piloting, vehicle parameters control, radio communication and navigation among them. The missions can be extremely long. Since the RFP is not actually on the vehicle his situation awareness is limited by this fact in a very important way. Distraction or misjudgements are common even with PF in airliners. Several recent accidents demonstrated that modern highly automated aerial vehicle reduce the awareness of the real aircraft situation even with extremely trained crews. The videogame effect of the pilot control station of modern UAV increases this problem. Distraction is a major factor for accidents even in car driving. For this reason a new, more immersive, headset based remote pilot station is proposed. A highly simplified external vision synthesizer is also proposed. The basic information are hierarchically ordered and displayed only if relevant. Multi-sensors image merging can be achieved. Augmented reality can be used to better information integration. HUD style flight data can also be depicted. Finally an active distraction and awareness evaluation software can be implemented.

Passive (environmental) distraction control

As it can be seen in Figure-1, the RFP interface seems to be extremely effective, multi-screen multi interfaces gives a complete control of all the aspects of flights, giving a complete set of information to the Remote Flying Pilot. This interface resembles the NASA "Glass Cockpit Concept". That began with the introduction of the MD-80 in 1979 (Figure-2). This interface outputs complete and exhaustive information of the aerial vehicle situation in well-ordered multi-function displays. This interface proved to be far from perfect for distraction control and situation awareness. Far better interfaces are depicted in Figures 4 and 5. Figure-4 is the traditional analog interface. A few instruments with red and green bands are separated from the outside by a plastic barrier. The PF attention is focused on the essential: outside instruments. For technical reasons these instruments were far from perfect. Especially the three arm altimeter brought several accidents due to reading errors. Figure-5 depicts a simplified HUD with synthetic produced simplified scenery. Only the essential is depicted. Since visual scanning is highly hierarchical, completeness is not the best solution for awareness. In modern aerial vehicles the FP inputs the data into the digital control system of the aircraft that actually flies it. In this way it is always an autopilot that controls the vehicle. When the Red Baron fell during WWI, it was devised that the pilot landed the aircraft before dying, since continuous corrective action was required to fly the Fokker Triplane. This is a perfect system to avoid distractions. Unfortunately it is far from safe. The actual FP situation is closer to the horse-drawn carriage where the driver keeps control on the horses, which are actually driving the wheeled vehicle. To avoid distraction blinkers are put to the horses. A similar strategy can be used with the PF: to avoid distraction a headset is far better that a multi-screen office environment (see Figure-5).

Figure-1. A RPF interface.

Figure-2. An advanced up-to-date Glass Cockpit example.

Figure-3. A traditional PF interface.

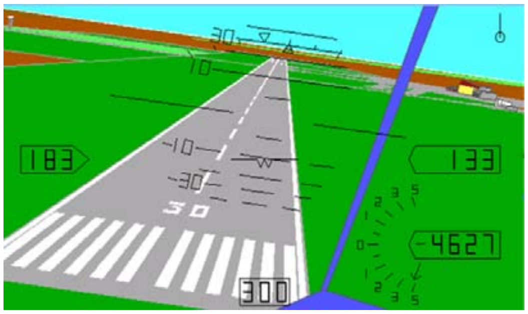

Figure-4. Simplified scenery with HUD.

Figure-5. Improved UAV remote control PF station.

In this case the PF has to turn on the outside camera to see the office environment or the additional screens. The computer outputs on the headsets all the data necessary in a highly selective way. This fact improves situational awareness. Finally, for a few train driver interfaces, a positive control is actuated by the elbow of the driver, that should press a selected spot in the cabin. This type of interface can also be implemented in the remote PF station.

Active distraction control

Distraction manifests itself in both reduced vehicle control and degraded object and event detection [1]. The process can manifest itself with eyelid closure (in the case of pilot fatigue) or eye glances away from flight correlated outside view and instruments (in the case of visual inattention). A second, and more difficult to detect, type of distraction is the selective withdrawal of attention. In this type of distraction, aerial vehicle control (directional control, speed and attitude maintenance) remains largely unaffected but object and event detection is degraded. The putative mechanism behind this type of distraction is the attention to thoughts. This process is difficult to detect and it might be indicated by open-loop visual scanning, restricted and reduced rate visual sampling of instruments and the outside, empty field myopia (e.g., fixating too close), and selective filtering of information based on expectations rather than the true situation. These different types of driver distraction suggest different types of measures and scenarios for their prevention. For example, measurement of direction, speed and attitude performance can evaluate a general withdrawal of attention. However these measurements says nothing about the selective withdrawal of attention that might be associated with a sampling device that perhaps does not require a visual resource, e.g. an automatic interrogation system coupled with voice-recognition system.

There is also a type of distraction effect due to "biomechanical interference". This refers to body shifts out of the neutral seated position, e.g., when reaching for a cellular telephone, leaning over to see or manipulate a device or taking something from the drawer. That this may be important is indicated by a recent reports that indicated the preponderance of cellular telephone-related crashes were associated with receiving calls, reaching for the cell phone and reading messages [2]. Similarly, the hand(s) occupied and off the throttle and stick degrade the pilot's ability to execute controls. These types of manual loads might involve, e.g., operating an external device, a hand-held cellular telephone, eating, drinking, lighting a cigarette, etc. These are a few of the types of biomechanical interference effects that a thorough safety control system should also be prepared to address. Except perhaps in retrospect, situational awareness and distraction cannot be measured directly. Indirect measures of safety-relevant distraction effects can be used. In first place PF eye glance behavior measures can be taken because of their importance of vision in piloting. This measures consist in glance durations, glance frequency, and scanning patterns that are part of this set of measures. PF performance measures are also popular because of their *prima facie* safety relevance.

Direction keeping, speed variations, driver reaction times to events are common measures from this class. PF control actions such as stick and throttle inputs can be used to make inferences about the distraction level. Finally, objective assessments of PF workload can used. Another, parameter is smoothness of operation.

In fact accident statistics indicate that pilots get into trouble precisely when they think everything is fine, i.e., in daytime, easy fling, no problem situations [3].

All this measurements can be implemented in a subroutine that, in case of doubt, may output on the headphone well defined questions. In this way it is possible to analyze the answer, in terms of readiness, voice level, voice frequencies and coherence of answer. If the PF is not responding measures can be taken to awake or to substitute him.

Implementation

With Virtual Augmented Reality (VAR) software it is possible reproduce accurately both the cockpit and the external view thanks to the helmet tracking system. Also the head-up display (HUD) and up-to-date flight instruments can be reproduced. In this way the PF (Pilot Flyng) station can be reduced to helmet, throttle/stick Joysticks with force feedback and a few additional LCDs. Another main advantage of VAR headsets is the possibility of reconfiguring the cockpit via software and to use it for several different UAVs.

In Figure-5 it is possible to see a logical schema of a VAR station: the pilot inputs via helmets (line of sight direction), flight controls (stick and throttle) and switches on joysticks the data in the AVCS software (Aircraft Visualization and Control System): The Aircraft Visualization and Control System take the data from the aerial vehicles, elaborates them and outputs the external view (external visual system) and the view of instruments (instrument visualization system). These two "images" are overlapped and mixed in a highly hierarchical visualization system, where only the relevant objects are depicted. To do so the external camera images from the aerial vehicle are analyzed and cleaned of all non relevant data. The data from the sensors are also to be included in the synthesizing process. The application of these ideas as discussed in this paper consists of the realisation of a VAR display system for a remotely piloted aerial vehicle. All the instruments are modelled via Head Up Display (HUD) while the external scenery is analyzed and only relevant elements for mission accomplishment or collision avoidance are represented. The PF have the possibility of a 360° field of view. Sound realism and true situation awareness can be then achieved. Software for distraction control and situation awareness can be easily implemented in the system. A synthetic audio interrogation system can keep track of the current state of alert of the PF. A flow diagram of the software is shown in Figure-6.

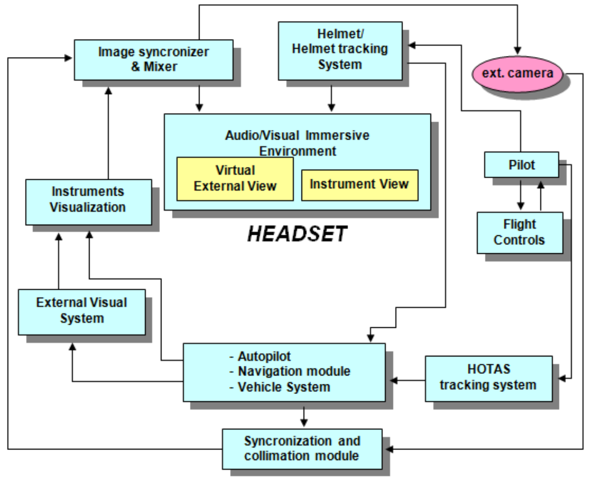

Figure-6. software block diagram.

The external camera is inserted as a switch activated device and can be displayed as a "picture in picture" or shadow mode.

Parallel versus distributed computing

Real-time simulation and visualization is huge CPU time consumer. Low resolution image (320x200x256 pixels-colors) generation needs large amount of data: 320x200 pixels x 256 colors x 15 frames/sec x 2 images (one for each eye) totals 491 Mb of data generated per second. In the 1024x768 resolution the amount of data calculated reaches 6 Gbyte per second: a huge demand also for modern computers. Nevertheless a good PF station needs very responding system. Increased performances are possible thanks to “parallel computing” and “distributed computing”. In parallel computing two or more CPU are mounted on the same board and a multithread, multitasking and parallel processing operative system provides to share processes on CPUs.

Actually, real flight data exchanged between the data communication interface and the visual engine (that computes scenarios) are very few, so this aspect of the PF station is not very time consuming. What it is really time consuming is the elaboration of images to detect the relevant information. This information should be integrated by sensors. This simplification process can be processed as the special effect sequence of digital movies. The movie people use the distributed elaboration environment.

In the distributed elaboration environment several different CPUs are plugged in separated boards linked only with Ethernet cards running TCP/IP or other net protocols. New applications can run on other calculators without increasing kernel elaboration: In fact it is easier and cheaper to add a new PC to the computing network, than purchase a new and more powerful computer for running kernel. For example in visual hierarchical reduction every single sensor can be elaborated by a PC connected to main process through TCP/IP link. The ultra complex images can also be split into parts and elaborated separately. Obviously synchronisation and correct initialisation are fundamental for instrument panel, command input and visual devices.

The visual system

The very simple visual system is based on polygonal plane facets (edge number ≥ 3) and is conceived for speed and fluent visualisation (more than 20 frames/s). Texture mapping, antialiasing and more realistic graphics are to be avoided. Helmet use introduces a new set of calculations to be performed (see figure 2). At first a rototraslation is performed on each corner $x_1(i)$, $y_1(i)$,$z_1(i)$ of every facet i; then another set of rotation matrixes is applied on the transformed coordinates $\{x_2(i), y_2(i), z_2(i)\}$ in order to obtain head/helmet perspective view. In this case it is assumed that the pilot keeps the nape on the headrest. By the way $\{x_2(i), y_2(i), z_2(i)\}$ are the landscape coordinates for a view aligned with airplane longitudinal axis. A smart renderer with Z-buffer, view clipping, object clipping, incremental object resolution, hierarchical object generation and double buffering has been implemented (as shown in Figure-4) in order to perform visualisation.

Performance requirement: helmet

Traditional simulation devices are based on monitors or projectors. Sophisticated visualisation systems perform multi-view point vision in order to increase realism: two or more images from different points of view are rendered and projected on different projection devices; however this procedure is very CPU time consuming. Less expensive and very interesting simulation enhancements can be achieved by introducing the virtual reality helmet. However helmets resolution represents a great obstacle in virtual reality development. Imagine t have a binocular Rif-style helmet with a 320x200 pixel resolution: this is enough for scenarios rendering, but absolutely insufficient for flight instruments reproduction. Imagine having a one hand analogic gauge with the following figures:

needle thickness = 1 mm;
angle of view (α) = 60 degrees (both vertical and horizontal, height/width = 1);
Needle distance (D) = 500 mm.

So the needle thickness to image width (T/W) ratio is (1):

$$\frac{T}{W}=\frac{1}{2D\tan\left(\frac{\alpha}{2}\right)}=\frac{1}{577} \qquad (1)$$

So, for a minimum line width of one pixel, helmet resolution should be at least 577x577. Theoretically a 640x480 helmet should be enough for this task.

Unfortunately, in order to obtain a sufficiently “straight line” on a raster display, antialiasing is to be used [4]. A minimum effective width of three pixels is then required. The practical minimal resolution is then threefold the theoretical one. Luckily, the commercial headsets capable of these performances are coming to the market.

The needle thickness of one mm is necessary both for “old” aeroplanes with traditional instrumentation (let’s think to the three-branch altimeter) and for “new” machines with EFIS (Electronic Flight Instrument System), so nothing can be made in order to avoid the “high resolution” requirement. Moreover, since helmets should consider the eye movements, high-priced wide-angle helmets are required to have a wide field of view. Various manufacturers offer angles up to 120 degrees. In this case the minimum practical resolution becomes 5200x5200.

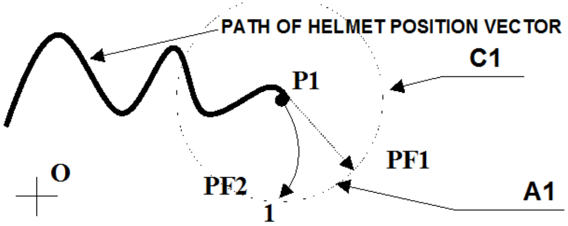

Figure-7. Head position tracking.

Helmets play a meaningful role in the immersive environment. The tracking system measures position and orientation. From the position and orientation of pilot’s head, the computer can determine how to display the virtual world so that the immersive effect takes place. When you turn your head the head tracker senses the change in position and angles, and adjusts the displays accordingly. The head tracker needs to be capable of taking a measurement of position and orientation at least 60 times every second (for a 20 frame/s draw-rate). The delay between tracking acquisition and display update should not exceed the 1/20th of a second. Any slower rate than this one causes the eyes and inner-ear give the brain conflicting information about which direction head is pointing. This is similar to what happens on a small boat in rough waters: it can make you seasick, or in VR terms, simulator-sick. As long as is not necessary to mix real and computer-generated images a precise position tracking is not necessary: within reasonable limits “what you see is where you are”. An improvement can be achieved by using smart future state point prevision algorithms for high-speed head movements. Starting from few of the previously tracked points the calculator can predict helmet/head future position so that the displayed image is close to the real head position. A useful algorithm for this operation is the “alpha blending” algorithm [5] (see Figure-7). The alpha-blending algorithm is based on the hypothesis that the future position will be in the area defined by the curvature and the tangent of the last point **P1**. An interpolation of the velocity modulus allows calculating a circumference C1 of possible future points for the time $t_0+\Delta t$, where t_0 is the current time and Δt is the time necessary to build the image. Alpha blending assumes that future point **PF** will be in the arc (A1) of C1 defined by **PF1** (intersection of tangent at **P1** with C1) and **PF2** (intersection of curvature circle at **P1** with C1). A position parameter can then be mapped on the arc A1 $u \in [0,1]$ ($u=0 \Rightarrow$ **PF≡PF2** and $u=1 \Rightarrow$ **PF≡PF1**). This parameter may be conceived so that the faster the speed of the helmet the closer is the future point PF to PF1. A parametric quadratic mapping law can then be defined by the following equation, with **v** being the intensity of the velocity vector at P1:

$$u = \left(\frac{|v|}{|v_{max}|}\right)^2 \text{ for } |v| \in \left[0, |v_{max}|\right] \text{ and } u = 1 \text{ for } |v| \geq |v|_{max} \qquad (2)$$

Even with some prevision of future position **PF**, very fast head movements give time lag. Luckily, when high-speed movements take place the eye is not capable to follow the movements. In this case the colours may expand in the direction of the movements or the vision can turn black. This phenomenon depends greatly on individuals: a first approximation curve is depicted in Figure-8. However at low speed this effect is compensated by pupil-eye movement, so vision obscuration due to speed can be neglected as a first approximation. In our visual system no transitional effect is applied from full to black view, so pupil eye movement is assumed at low head turning rate. The acceleration effect on vision can be successfully used for our PF interface. Usually this phenomenon takes place in two phases, at first the images becomes defocused and narrow (tunnelling), then blackening occurs. In our visual system the tunnelling effect takes place at acceleration of 3g and -2g with blackening at 6g and -4g. This is very useful since the remote PF cannot feel acceleration.

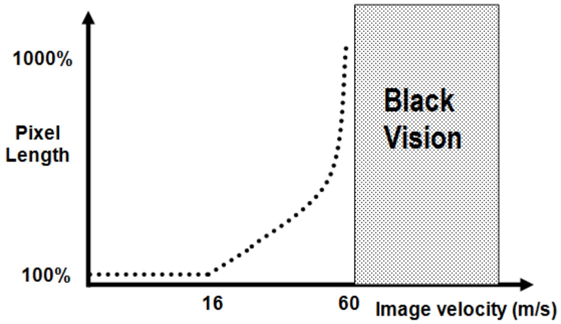

Figure-8. "Black vision" model.

Head-Up display (HUD)

In real aircraft, HUD is a device that collects flight information from the instruments and then projects it into a specially designed piece of glass, called a combiner, located between the pilot and the windshield. The projected image is focused toward infinity so that when the pilot's eyes are focused on the outside world the instrumentation comes into the view. Normally head-up displays are readable only when pilot's eyes are pointed to the front screen.. In a virtual reality environment it is possible to render HUD flight information over the scenarios depicted on the virtual reality helmet (see black lines and numbers in Figure 4). HUD data are then always superimposed to external view. In this case, no real instruments and cockpit reconstruction is necessary and a large amount of computations are saved.

Motion implementation

To increase situation awareness a motion can easily implemented. With the HUD-HOTAS simulator introduced in this paper, one of the most expensive device in a full flight simulator, the motion system, turns to be very simple since only the pilot's seat has to be moved. Due to drastic reduction in movable mass (down to 150 kg), large power savings can be realised. Also inertia forces are dramatically reduced and a very accurate 6 DOF simulator of the aerial vehicle dynamics can be implemented with limited resources. This very simple virtual device can also be successfully used for low level, low speed flight conditions which are known to be the cause of many accidents in commercial, sport and military flight.

CONCLUSIONS

Some techniques of virtual reality that may be used for the implementation of a UAV remote pilot station are described in this paper. The idea of a helmet based on flight simulation experience is discussed. Luckily with parallel computing, it is now possible to implement a fully "virtual" flight simulation. In fact the resolution necessary for the readability of cockpit instruments is up to 5000x5000 pixels that is at reach of up-to-date helmets and computers. However the advantage of the helmet solution is important since full 360° visibility and hyerachical aggregation is outside information are possible. In this case sophisticated techniques of future position determination should be used to reduce the time lag between computers generated image and true head position. The HUD-HOTAS pilot station described in this paper avoids the high-resolution requirements of cockpit instruments by depicting flight information directly on the visual system in the same way of the commercially available HUDs. On the other hand, in the HOTAS approach the pilot flies with hands on stick and throttle and uses only the switches on these two devices. Several HUD modes are available to perform the functions that are necessary for take-off, level, land, abnormal and emergency flight conditions. Situational awareness is highly improved in this immersive virtual environment. Pilot distraction and awareness can be positively measured and appropriate action can be taken to keep it during the whole flight.

REFERENCES

[1] Brown I. D. 1994. Driver fatigue. Human Factors, 36(2): 298-314, (National Police Agency of Japan, 1998)

[2] National Police Agency of Japan. 1998, August. Car-phone-related traffic accidents during the first half of 1998. Handout presented at ITS America Safety and Human Factors Committee Meeting, Dublin, OH, July 28, 1999.

[3] Wiacek C.J. and Najm W.G. 1999. Driver/vehicle characteristics in rear-end precrash scenarios based on the General Estimates System (GES) (Paper No. 99PC-415). Warrendale, PA: Society of Automotive Engineers.

[4] Alawsky R.S. 1994. The Science of Virtual Reality and Virtual Environments. Addison Wesley, ISBN 0-201-63171-7.

[5] Earnshaw R. A., Watson D. 1993. Animation and Scientific Visualization Tools & Applications, Academic Press Limited, London, UK.

[6] L. Piancastelli, L. Frizziero, S. Marcoppido, A. Donnarumma, E. Pezzuti. 2011. Fuzzy control system for recovering direction after spinning. International Journal of Heat and Technology. 29(2): 87-93.

[7] L. Piancastelli, L. Frizziero, S. Marcoppido, A. Donnarumma, E. Pezzuti. 2011. Active antiskid system for handling improvement in motorbikes controlled by fuzzy logic. International Journal of Heat and Technology. 29(2): 95-101.

[8] L. Piancastelli, L. Frizziero, E. Morganti, A. Canaparo. 2012. The Electronic Stability Program controlled by a Fuzzy Algorithm tuned for tyre burst issues. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006, 9(1): 49-68, Allahabad, India.

[9] L. Frizziero, I. Rocchi. 2013. New finite element analysis approach. Published by Pushpa Publishing House. Far East Journal of Electronics and

Communications. ISSN: 0973-7006, 11(2): 85-100, Allahabad, India.

[10] L. Piancastelli, L. Frizziero, E. Pezzuti. 2014. Aircraft diesel engines controlled by fuzzy logic. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(1); 30-34, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[11] L. Piancastelli, L. Frizziero, G. Donnici. 2014. A highly constrained geometric problem: The inside-outhuman-based approach for the automotive vehicles design. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(6): 901-906, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[12] L. Frizziero, F. R. Curbastro. 2014. Innovative methodologies in mechanical design: QFD vs TRIZ to develop an innovative pressure control system. Asian Research Publishing Network (ARPN). Journal of Engineering and Applied Sciences. ISSN 1819-6608, 9(6): 966-970, 2014, EBSCO Publishing, 10 Estes Street, P.O. Box 682, Ipswich, MA 01938, USA.

[13] L. Piancastelli, L. Frizziero, I. Rocchi. 2014. A low-cost, mass-producible, wheeled wind turbine for easy production of renewable energy. Published by Pushpa Publishing House. Far East Journal of Electronics and Communications. ISSN: 0973-7006, 12(1): 19-37, Allahabad, India.

[14] L. Piancastelli, L. Frizziero, E. Morganti, A. Canaparo. 2012. Fuzzy control system for aircraft diesel engines. Edizioni ETS. International journal of heat and technology. ISSN 0392-8764, 30(1): 131-135.