2015

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As touch screens are everywhere in the consumer market Thales has launched in depth evaluations on their introduction in the cockpit. One of the challenges is to verify its compatibility with in flight use under turbulence conditions, including light, moderate and severe. In flight accelerometer collections were performed to provide us with a baseline for choosing between possible simulation solutions. Thales recognized early on the need for such a tool as it would enable us to define recommendations for our HMI designs. The objectives were first to validate specific complex touch/gestures using all the potential of touch interactions for novel cockpit Human Machine Interfaces and second to look into the various physical anchoring solutions capable of facilitating touch screens interactions in aeronautical turbulent environments. Given the 6 axis accelerometer profiles that were collected, a number of potential candidate simulation platforms were selected. They were reviewed in terms of performance and cost. Our final candidate is an Hexapod structure capable of reproducing those profiles with acceptable validity. This paper presents the works that enabled us to validate such an hexapod as a viable simulator for our tests and the development of an avionics platform for touch interactions under light to severe turbulences. Pilots were asked to evaluate 6 simulated profiles designed to mimic the “inflight” references. Tests were performed to validate the best profiles for each level of turbulence. The selected profiles were then used to evaluate our touch screen propositions in light, moderate and severe turbulent conditions. Preliminary results are presented.

The ubiquity of touch technology and its upcoming in cockpits

The trend of touch technology for interaction is undisputed. DisplaySearch, a market analysis firm, forecasts it to grow to over $16 billion by 2016 and $31.9 billion by 2018. The market growth is being driven by increased demand from applications such as iPads and other tablet PCs, smart phones, and emerging notebook PC designs. (Sieh, 2010). More recently another analyst confirms the trend and the touch screen market grew from $1.5 billion in annual revenues in 2008 to over $6 billion in 2011 (Blanco, 2012). Since the uprising of the inevitable Iphone, touch interactions overtook the cellphone industry. Nowadays, kids try to interact spontaneously on any screen they come by as if it “obviously” had to be a touch screen.

Facing such an inevitable trend, the AV2020 full touch screen cockpit concept has been developed (2020). It comprises multiple seamless touch screens in an integrated approach to pilots’ HMI demands. Yet implementing touch technology in a liner cockpit means complying to part 25 aircraft certification. The process is thorough and specifies that the design of systems should take into account aeronautical effects (such as turbulence) and the way they affect the efficiency of pilots’ interactions. Hence, an human factors evaluation was decided to alleviate the risk on usability of touch displays in turbulence, refine design recommendations for interactions with touch technology (HMI design and physical installation) and prepare certification.

Characterizing aeronautical turbulence

Origin of turbulence

Even with limited flight experience one can relate to the term “turbulence” in flight. Usually the captain orders passengers to their seat with their seat belt tightened due to upcoming turbulence. Atmospheric turbulence is defined as “small-scale, irregular air motions characterized by winds that vary in speed and direction” (Encyclopedia Britannica, 2013). One must note that turbulence does not compare to a vibration, as it is chaotic by nature and not cyclic.

Intensity of turbulence

Turbulence is separated into four levels of intensity. Each different level of intensity can be described from both ‘reaction of the aircraft’, as well as the ‘reaction inside the aircraft’. These four levels are described below.

Table 1.

Turbulence Reporting Criteria Table, (Aeronautical Information Manual, FAA).

Intensity	Aircraft reaction	Reaction inside aircraft
Light	Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, yaw). Report as **Light Turbulence** or Turbulence that causes slight, rapid and somewhat rhythmic bumpiness without appreciable changes in altitude or attitude. Report as **Light Chop.**	Occupants may feel a slight strain against seat belts or shoulder straps. Unsecured objects may be displaced slightly. Food service may be conducted and little or no difficulty is encountered in walking. • Occasional−Less than 1/3 of the time. • Intermittent−1/3 to 2/3. • Continuous−More than 2/3.
Moderate	Turbulence that is similar to Light Turbulence but of greater intensity. Changes in altitude and/or attitude occur but the aircraft remains in positive control at all times. It usually causes variations in indicated airspeed. Report as **Moderate Turbulence** or Turbulence that is similar to Light Chop but of greater intensity. It causes rapid bumps or jolts without appreciable changes in aircraft altitude or attitude. Report as **Moderate Chop.**1	Occupants feel definite strains against seat belts or shoulder straps. Unsecured objects are dislodged. Food service and walking are difficult.
Severe	Turbulence that causes large, abrupt changes in altitude and/or attitude. It usually causes large variations in indicated airspeed. Aircraft may be momentarily out of control. Report as **Severe Turbulence**	Occupants are forced violently against seat belts or shoulder straps. Unsecured objects are tossed about. Food Service and walking are impossible.
Extreme	Turbulence in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage. Report as **Extreme Turbulence**	

The objective of such a description is to recognize turbulence by its effects to enable reporting. As our objective is to analyze the effect of various controlled turbulence levels (in a simulator) on touch screen usability, we had to analyze beyond that description to come up with metrics on what such levels of turbulence mean in terms of displacement and acceleration.

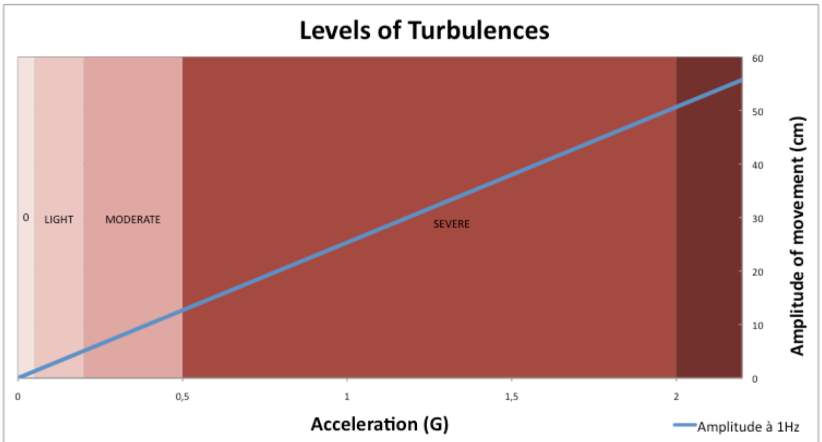

Figure 1. Level of turbulence as a function of acceleration and displacement

Figure 1 represents the relationship between displacement and accelerations. The blue line characterizes the effects at 1Hz. In a sinusoid, displacement of 25 cm per second implies a maximum acceleration of 1m/s.s (1G). One can undergo a maximum of 2 Gs when submitted to a displacement of 50 cm per second. Using such relationship, the various levels of turbulence were approximated with regards to maximum acceleration and maximum displacement withstood. We focused on the effects of vibration being between 0,2 and 7Hz as they are predominant on the control of hand/arm movement (Berthoz, 1981). At one end, for a frequency of 0,2Hz one would need 12 meters of displacement to reach an acceleration of 2Gs. On the other hand, the higher the frequency, the flatter the line, at 7 Hz, one would reach 2gs for a displacement of only 1cm. This preliminary analysis enabled us to focus our search for an adequate simulation platform. what we are looking for should be able to reproduce large displacements at low frequencies (i.e. vibration pods are no solution, as they produce small displacements at high frequencies).

The best solution was the Hexapod. There are many types of hexapods and only the high end ones are able to reproduce the levels of movement characteristic of aeronautical turbulence. We need: 3 axis of acceleration, X, Y & Z, 3 angular accelerations and ultimately a certain capacity of displacement coherent with those encountered in a real aircraft.

Environment simulation design

To complete our initial analysis we started collecting in flight data on a Socata TBM700 aircraft. We used a SGB IG-500N GPS enhanced miniature Attitude and Heading Reference System (AHRS) that delivers attitude and position measurements. It was installed near the center of gravity of the aircraft to collect movement and accelerations (3 angular + 3 linear) at 100Hz when submitted to various levels of turbulence.

Hexapod limits integration (tech evaluation)

The inflight recordings provided flight path (georeferenced) and 100Hz sampling of accelerations (3 angular + 3 linear) on any given path. The data had to be transformed, as an Hexapod cannot process them directly (being fixed to the ground the machine cannot understand georeferenced movements…). The mathematical transformation produced XYZ & 3 Angular accelerations around a stabilized georeference that would be the center of the hexapod, hence producing the turbulence profiles. The Hexapod we chose being the property of the Ecole Nationale Supérieure des Arts et Métiers (ENSAM), we verified that the profiles were within the maximum displacement (+/-50cm) and the maximum accelerations (+/-2G). Minor adjustments were made mostly by limiting replay frequency between 0,2 and 7Hz.

Profile adaptation (expert evaluation)

Working with a Flight test pilot, we adjusted the profiles. First a 22,5 seconds sample was chosen based on diversity (maximum displacements and accelerations within the sample) and lack of symetry (the cahotic nature of turbulence had to be preserved). That sample was the reversed and joined to the original one making a 45s profile. The profile was run sevel times at ¼ displacement (¼D) then at ½ displacement (½D) then full (1D) on an empty seat, for security reasons. Next our test pilot was submitted to the same progressive runs to perform an initial assessment of the profiles. We optimised then the initial Sample (1D) playing on maximum range of displacement, dilating or compressing parts of the sample, adding or reducing accelerations, mostly Z and Y (the front back acceleration being rare in an AC). Every alteration implied a progressive ¼, ½ and Full test with our test pilot. The objective was to provide 3 profiles of turbulence, for the light, moderate & severe levels of turbulence. In the end we selected 6 profiles that should cover the desired turbulence levels to be reproduced on an Hexapod.

Subjective Acceptability Evaluation

Means & Method

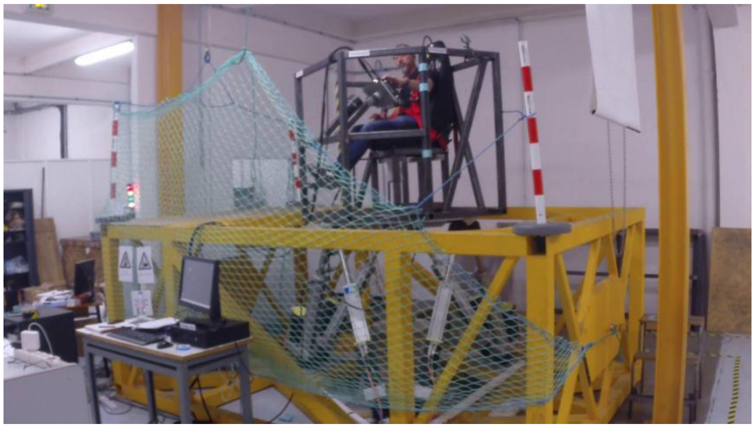

Figure 2. The Hexapod at ENSAM with the test bench on top

The evaluation took place at ENSAM in Bordeaux and had a double objective, first a pilot assessment of the levels of turbulence played by the Hexapod (figure 2) and second a in depht evaluation of touch interactions performance when subjected to various levels of turbulence. Only the first evaluation is presented here. The Hexapod (+/-2g, +/- 50cm Y,X,Z displacements and 3 axis angular acceleration), property of ENSAM Bordeaux was fitted with a specific “cage” replicating the conformation of the AV2020 cockpit design. The design of the cage was contracteed to ENSAM on detailed specification to ensure the realism of multiple screen positions. Six 45s profiles (table 2) were pre programed on the hexapod and could be played on demand.

Subjects

30 subjects performed this evaluation: 5 left handed, 25 Right handed; 4 women, 26 men; 6 aged 20—29, 11 aged 30-39, 8 aged 40-49, 5 aged 50-59; 7 men had more than 100h of piloting experience (5 with significant flight experience); 9 reported being sometimes sea sick or simulator sick.

Turbulence acceleration profiles

Table 2.

Turbulence profiles to be tested (acceleration in m/s^2)

Profile	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
Maximum	1,38	2,29	5,51	4,12	5,52	8,11
Mean	0,35	0,65	1,33	1,28	1,53	2,60
Median	0,31	0,57	1,15	1,11	1,32	2,29
Turbulence level	Less than light	Light moderate	Moderate high	Moderate low	Moderate High	Severe

A typical run would comprise the 6 turbulence profiles comparative evaluation then the touch screen evaluation under turbulence and would last 1h 30mn on average. A pause in the middle was added to accommodate the test subject, the experience being somewhat tiring.For the subjective evaluation of the turbulence level, the protocol was quite simple. 7 pilots (more than 100h of piloting experience) ran each profile and were asked to evaluate the realism of the profile as a turbulence one could encounter in an aircraft, second to rate the level of turbulence the profile would compare to. An example of the questionaire is shown table 3.

Table 3.

Subjective evaluation of simulated turbulence profiles

Turbulence profile played	**Does it feel like real in-flight turbulences?**	**Please estimate the level of this turbulence profile**
- - -	not at all ◆———◆ Perfectly	0 ◆——◆ light ◆——◆ moderate ◆——◆ Severe ◆

Results

Though our sample of pilots was small, our results show a great coherence and little variability. Since that experiment, more pilots have assessed the levels of turbulence that the hexapod can simulate but with no significant change in the results. Results are shown on figure 3, all profiles have a rating superior to 5/10, 5 out of 6 profiles are juged higher than 8/10 and for all profiles there is very little dispersion in the ratings. The higher the level of turbulence the smaller the dispersion of the pilots evaluation. Levels P1 &P2 were juged light, the levels P3,P4 & P5 were juged as moderate and the last profile P6 was rated severe.

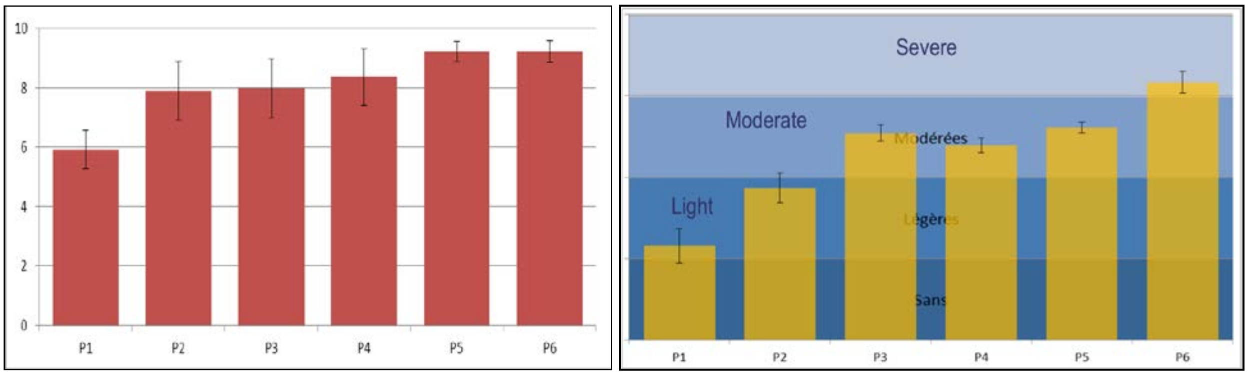

Figure 3. Results: on the left, estimated “realism” of the profile on a scale from 0 (not realistic at all) to 10 (extremely realistic). On the right: estimated level of simulated turbulence profiles.

Conclusion

The pilots interviewed are all agreeing on the quality and representativeness of the hexapod as a means to reproduce turbulence (small distribution of answers).The Hexapod movements are juged similar to real turbulence with a high level of confidence, except for the lowest level. It appears to be less realistic than the others (though still over the average). Pilots reported on debriefing that the low displacements as witnessed on the lowest profile were harder to feel thus to compare to a memorized experience. Though P1 could still be accepted as representative of levels of turbulence, it was not selected in the end for future trial. The Hexapod was juged adapted to the silmulation of light to severe turbulence profiles and while there is a pilot consensus on the quality and representativeness of all the profiles, only 3 levels were chosen on the 6 prepared as being more representative for future evaluations: P2 to simulate light turbulence; P5 to simulate moderate turbulence; P6 to simulate severe turbulence.

References

Berthoz, A. (1981). Effets des vibrations sur l'homme In J. Scherrer et al. ed. lit.-Précis de Physiologie du Travail.

Blanco, R. (2012), Nothing Touches This Market… for The Penny Sleuth. Retrieved from http://pennysleuth.com/nothing-touches-this-market/

Encyclopedia Britannica, aeronautical turbulence definition. Retrieved from http://global.britannica.com/EBchecked/topic/41528/atmospheric-turbulence

Hsieh, C. (2010), Touch Panel Market Research, Retrieved from http://www.displaysearch.com/cps/rde/xchg/displaysearch/hs.xsl/touch_panel_market_analysis.asp

Regulations, F. A. (2008). Aeronautical Information Manual. Retrieved from **http://www.faa.gov/atpubs**

Wagtendonk, W. (2003). *Meteorology for Professional Pilots.* Bay of Plenty, New Zealand: Aviation Theory Centre (NZ) Ltd.