Abstract

Analysis of Two-Alternative Decision Errors in a Videopanorama-based Remote Control Tower Working Position for Quantifying Operator Performance

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Future remote control of small low traffic airports (Remote Tower Operation, RTO) will rely on the replacement of the conventional control tower out-of-windows view by a panoramic digital reconstruction with high resolution and pan-tilt zoom (PTZ) video cameras as basic sensor system [1]. State of the art technology for a digital videopanorama is presently limited by a visual resolution of typically 1/30° per pixel (2 arcmin) as optimistic estimate under optimal contrast and visibility conditions [2]. This resolution is about half as good as that one of the human eye, achieved with HD-format camera technology and 4 - 5 cameras for a 180° - 200° horizontal panorama with 45 - 60° vertical field-of-view. The resolution and contrast deficit (due to technical contrast limitations) as compared to the human vision requires the use of a pan-tilt zoom camera for achieving the operationally required object detectability.

In the present work the detailed analysis of two-alternative decision experiments shows that despite the inclusion of a (analog, PAL) PTZ with selectable zoom factor setting Z = 2 – 16 (VGA: 640x480 pixel, viewing angle 26° - 3°) a significant increase of decision errors under RTO as compared to the out-of-windows view in the conventional control tower (TWR) is measured if non-answers are interpreted as errors (worst case assumption).

As part of an operational passive shadow-mode test eight air-traffic controllers observed various flight-maneuvers during airport circling, like bank angle and altitude changes, and gear-up / gear-down, landing light-on / light-off situations, under limited response time. The response matrix of two-alternative decision tasks as obtained by measuring the hit (H) and false alarm (FA) rates when reporting, e.g. gear-up vs. gear-down situation during approach, were analysed using Bayes inference and detection theory (SDT). The latter method in principle allows for separating discriminability from subjective response bias. In previous experiments it was successfully used for deriving video-framerate requirements which minimize prediction errors in dynamic scenarios [3].

The present analysis provides an estimate of the increase of decision error probability at the RTO controller working position (RTO-CWP) as compared to the conventional tower condition (TWR-CWP). It is quantified by a discriminability (d'-) decrease using signal detection theory (SDT). A Bayes inference analysis based on the same data provides a corresponding increase for risk of false decisions. This performance decrease is observed only when interpreting all non-answers as errors, and it remains significant when assuming non-answers to be wrong answers by chance (i.e. only 50 % of non-answers interpreted as erroneous answers).

As a hypothesis this significant deficit of RTO-CWP performance is related to an increase of time pressure TP (= required time Tr/ time available Ta, e.g. 10 s for the gear-down maneuver, and Tr(RTO) > Tr(TWR on average) due to image quality and PTZ usability deficits. We use the Perceptual Control Theory / Information processing (PCT/IP-) based exponential time pressure (TP) model of Hendy et.al [4] for deriving an initial estimate of the model parameters based on the TWR and RTO decision errors. Our preliminary conclusion is the request for more automation in the RTO-CWP (e.g. provision of visual cues through radar label superimposition / augmented vision) to compensate for the technical limitations. Because the present experiment provided only two data points of the (derived) independent variable for the exponential model test (two average TP-values for work positions TWR and RTO, although with different aircraft maneuvers), the support (or falsification) of the TP-hypothesis originating from image quality and PTZ-usability deficits requires a more appropriate experimental setting. Corresponding experiments are presently under preparation (e.g. with systematic Ta-(or TP-) variation through different degrees of automation).

[1] M. Schmidt, M. Rudolph, B. Werther, N. Fürstenau, *Development of an Augmented Vision Videopanorama Human-Machine Interface for Remote Airport Tower Operation.* Proc. HCII2007 Beijing, Springer Lecture Notes Computer Science 4558, 2007, 1119-1128.
[2] Schmidt, M., Rudolph, M., Papenfuß, A., Friedrich, M. Möhlenbrink, C., Kaltenhäuser, S., Fürstenau, N., (2009). *Remote airport traffic control center with augmented vision videopanorama.* In: Proc. 28th IEEE-DASC 2009, Orlando, pp. 4.E.2-1 – 4.E.2-15
[3] Ellis, S. R., Fürstenau. N. and Mittendorf M.. *Frame Rate Effects on Visual Discrimination of Landing Aircraft Deceleration: Implications for Virtual Tower Design and Speed Perception.* Proceedings of the Human Factors and Ergonomics Society 55th Annual Meeting, Sept. 19-23, 2011, Las Vegas, NV USA, pp. 71-75.
[4]K.C. Hendy, J. Liao, P. Milgram, *Combining Time and Intensity Effects in Assessing Operator Information-Processing Load,* Human Factors, vol.39, (1), (1997) 30-47