Abstract

Model based Analysis of Two-Alternative Decision Errors in a Videopanorama-based Remote Control Tower Work Position

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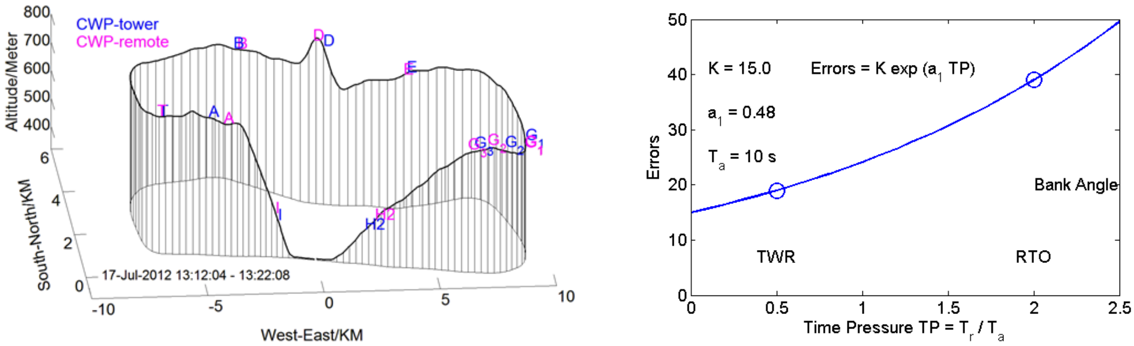
Remote Control Tower operation (RTO) for airport ground traffic control without the need for a local physical tower building is presently in the transition phase from research to the prototype with testing in the operational environment (e.g.[1][2][3][4][5]). State of the art technology is based on a digital videopanorama with HD-format camera technology, e.g. 4 - 5 cameras (focal width of 8 – 13 mm) with 45 - 60° vertical field-of-view for a 180° - 200° horizontal panorama. It is presently limited by a visual resolution of typically 1/30° per pixel under good visibility conditions (= 2 arcmin, about half as good as the resolution of the human eye). This is the Nyquist limit of the modulation transfer function (MTF) which typically shows a significant contrast reduction (dependent on the quality of the optical system) down to 10 - 20% of the maximum value (see also the spatial standard observer model of [7]).

Initial analysis of a first validation experiment including aircraft maneuver observation in the control zone during aerodrome circling (left Figure) has shown that a specific subset of two-alternative decision tasks [5] as part of a larger set of operationally relevant tasks of controllers [4] exhibit a significant performance decrease of the remote as compared to the conventional tower work position (RTO vs. TWR-CWP). This RTO-CWP deficit was measured despite the use of a manually controlled pan-tilt zoom camera (analog PTZ with PAL TV-resolution, selectable viewing angle 26° - 3°) which due to its higher resolution was expected to compensate for the videopanorama resolution and corresponding detectability limitations.

The present analysis includes a model based approach and extends the initial data evaluation of two-alternative decision tasks [5] which was based on a subset of the complete two-alternative decision data. As part of the passive shadow-mode test [3,4,5] eight air-traffic controllers observed various flight-maneuvers during airport circling of a DO-228 test aircraft (left Figure), like bank angle and altitude changes, and gear-up / gear-down situations. The response matrix of the two-alternative decision tasks as obtained by measuring the hit (H) and false alarm (FA) rates when participants reported on the observation of, e.g. gear-up vs. gear-down situation during approach, yielded a significant increase of decision errors under RTO-CWP conditions, when interpreting non-answers as errors. Under this worst case assumption (non-answer = error) the previous analysis provided an estimate of the increase of decision errors under RTO conditions as quantified by a discriminability (d'-) decrease by a factor of up to 3, as compared to the conventional TWR-CWP [5]. The d'-values obtained with standard methods of signal detection theory (SDT) were complemented by Bayes-inference analysis based on the same measured H and FA conditional (a priori) probabilities which provided a corresponding increase for risk of false decisions.

As a hypothesis the significant increase of RTO-CWP errors is now related to an increase of time pressure TP = required time / time available, with limited decision time available Ta = 10 s. For the specific two-alternative decision tasks Ta was mostly sufficient for TWR-CWP decision making, however apparently much more often not so for RTO-CWP. We use the Perceptual Control Theory (PCT) based Time Pressure (TP) model of Hendy et.al [6] for deriving an initial estimate of the two exponential model parameters based on the TWR and RTO decision errors (see right figure). This result is compared with a new SDT and Bayes

inference analysis, however now applied to the full dataset. Discriminability (d') and error-risk values confirmed the previous results, however only for observation of A/C maneuvers without altitude change. This turned out to be due to the participant's selection of radar information for altitude change observation instead of the out-of-windows / PTZ-view, i.e. the same information source under both conditions. Interestingly the TWR-RTO performance difference with regard to d' and Bayes risk remains significant also when assuming a chance interpretation of non-answers (i.e. only 50% erroneous).



Left Figure: GPS-track of test aircraft during passive shadow mode tests showing aerodrome circling with numbered events like bank angle changes (A), altitude changes (D), and gear-out/in (H), indicating TWR/ATC and remote/RTC decision locations on the trajectory. Vertical lines end at average airport height 319 m. Observers at tower position of ca. (0,0,350 m) with 200° RTO-panorama viewing north.
Right Figure: Example of time pressure model based analysis of decision errors: estimate of time pressure (TP) model parameters with response times Tr arbitrary selected as Tr(TWR) :=5 s < Ta, Tr(RTO) := 20 s > Ta.

The perceptual control theory with time pressure as proposed explanation for the non-answer and decision error-increase respectively leads to the hypothesis that suitable RTO-automation such as augmentation of the far view by superimposition of approach radar information for aircraft position cueing and automatic zoom camera tracking via image processing or Mode-S /ADS-B data fusion together with improved operator training might eliminate the observed RTO-CWP performance deficit. The confirmation of the TP-hypothesis originating from PTZ-usability deficits as explanation of the RTO-CWP performance problem of course requires a more appropriate experimental setting (e.g. systematic TP-variation) which is presently under preparation.

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