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Presentation for KSAS-JSASS, Jeju-do, South Korea
Thursday November 20th 2008 – Session C.3 (14:10-14:30)
(Feel free to contact me with comments/questions on this content; e-mail: jorg – at – entzinger – dot – nl)

A large part of my paper is literature overview and theoretical background. In my presentation I will try to put this into perspective and visualize the most important principles of my research.

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[video shows: 1) plane from outside; 2) cockpit window view; 3) control column deflection; 4) combined videos]
This shows the final approach to landing (last part of glide and flare)
The question is: what is the pilot looking at and how does he decide the proper control inputs

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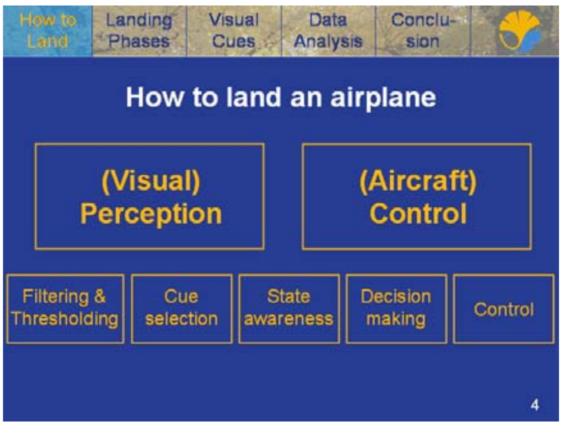
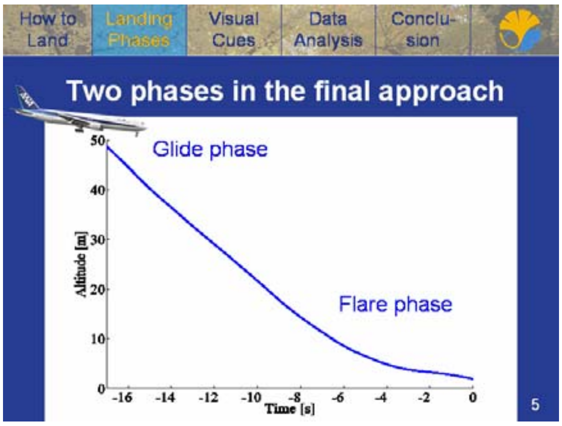
If we know how the pilot "sees" the aircraft motion and how he decides on his control, it will be easier to train new pilots, we can make more efficient and effective simulators, and it can help in understanding and recognizing visual illusions and thus increase air safety, etc. etc.

4 

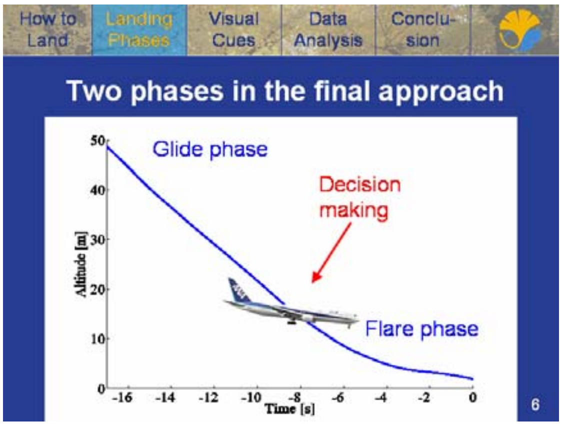
The two main points in my research are PERCEPTION (how we sense the world around us) and CONTROL. These 2 themes contain several (conscious or subconscious) sub-stages when it comes to aircraft control by a human pilot.

- Some cues may be too small (or too big) to be visible, relative brightness or contrast levels may be insufficient, or cues may be dominated by other cues
- Some cues contain better/more/easier accessible information than others, the pilot is trained to use those cues and ignore others
- The pilot has a mental model of "what looks right" and what certain deviations of that "ideal image" mean (e.g. too high, too fast, …)
- The pilot makes decisions to adjust, go-around, initiate flare etc
- The pilot continuously controls the aircraft according to the difference between perceived and desired state

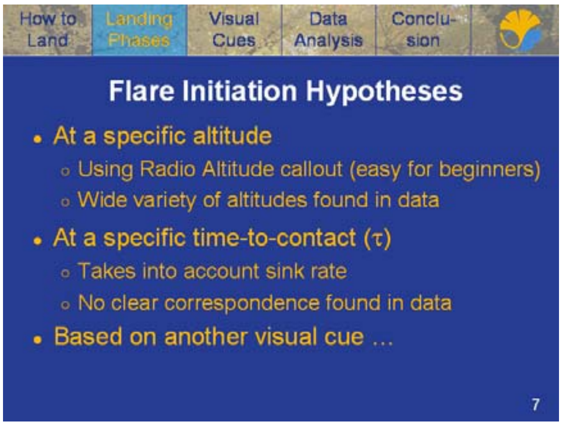
5 

Currently I investigate 2 phases in the final approach to landing (if successful, maybe I add turn-to-final later) [Animation]

1) The glide phase, where the pilot should track a straight path with about 3deg slope in the vertical plane
2) The flare phase, where the pilot should pitch up to reduce sink rate

6 

In my paper and in this presentation, I focus on the decision making regarding the initiation of the flare.

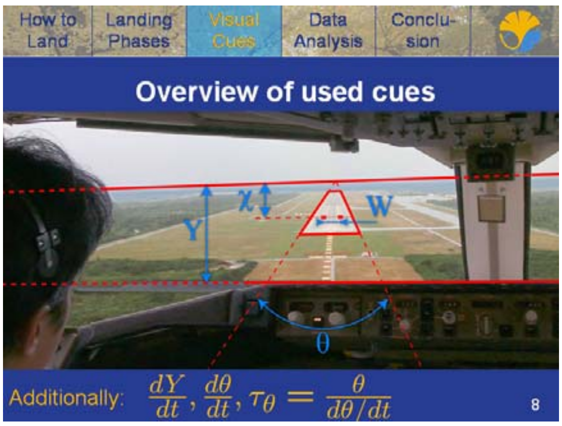
7 

In pilot modeling and pilot training literature, several cues have been suggested for judging the proper moment of flare initiation.

Often it is said that the flare should be started at a specific altitude above the runway. For beginning pilots, the radio altitude callouts would help to know when to flare. However, our data show a wide variety in flare altitudes, and experienced pilots confirm that they have developed a more "refined" sense of what is the right moment to flare.

Another cue put forward is the time-to-contact (for instance altitude divided by sink rate), sometimes expressed as "flare altitude is 10% of the sinkrate in ft\min". Although this method takes into account the important variable "sinkrate", this cue also doesn't match very well with our data.

It is thought that the pilots use another VISUAL cue to decide the proper moment to flare. I will now discuss visual cues in general and come to propose a cue for flare timing.

8 

For longitudinal motion, there are many cues available to the pilot, these are the ones I use in this research. X is the "implicit horizon". When maintaining a constant glide slope, with the markers as aim point, the "implicit horizon" is constant. This is thought to be an important cue for keeping the glide path.

X ◊ glide slope
Y ◊ pitch attitude (dY ◊ pitchrate)
W ◊ distance
Theta ◊ altitude (dtheta ◊ altitude, sinkrate; tau_theta ◊ time to contact)

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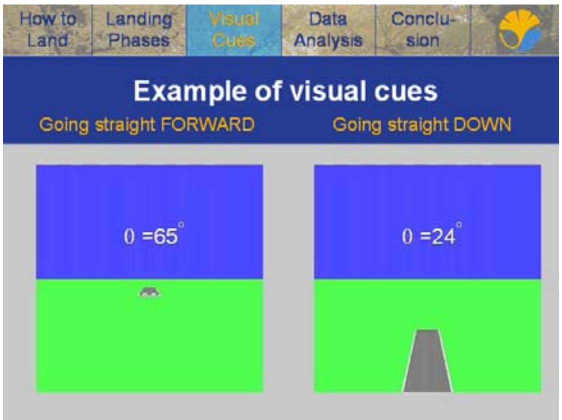

[videos] show how the scene changes when moving forward (left) or down (right) at CONSTANT speed
When moving forward, the shape of the runway is constant (the apparent angle between the side lines, theta, is constant). It only changes in size. When moving down, the shape changes (theta, gets bigger). Even at constant sinkrate, theta increases more than linear.

Actually, when moving DOWN at CONSTANT speed, the angle increases faster and faster. In the beginning you can almost not see the sideline rotating, but in the end it rotates very fast. Thus not only theta, but also the derivative of theta contains altitude information.

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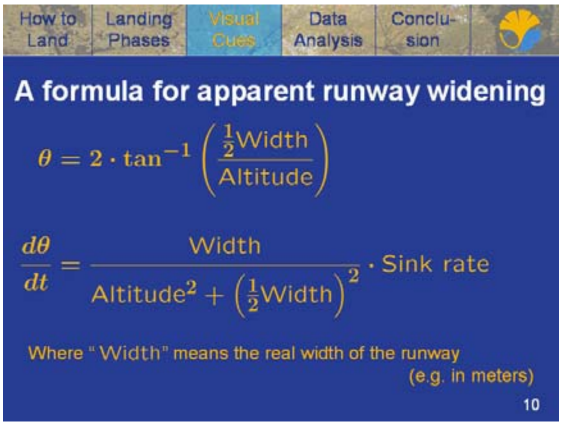

Using some mathematics (geometry, calculus, linear algebra) these formulas can be derived
It is important to note that dtheta/dt (the change of runway angle) includes both the altitude and the sink rate. These state variables were found to be important for de decision of flare timing. Therefore, dtheta/dt is a suitable candidate cue.

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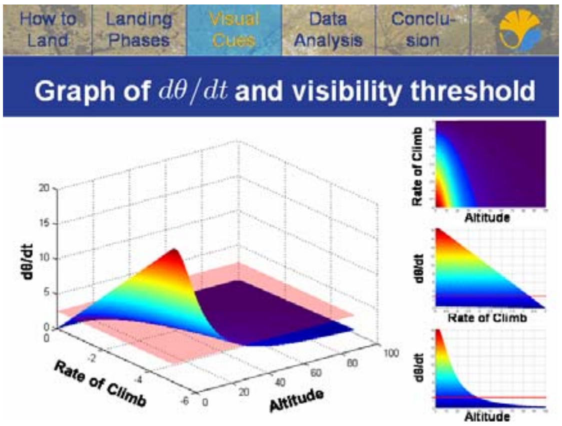

If we plot the formula, we find this surface. The transparent red layer indicates a 2.5deg/sec threshold, it is thought that below this, humans can't see the movement. (However, many researchers find very different values, so I think a special experiment, focusing on perception of the runway should be done to find the threshold value for this case, in order to verify whether dtheta/dt is really a possible cue)

I will now show how this cue relates to the pilot's control

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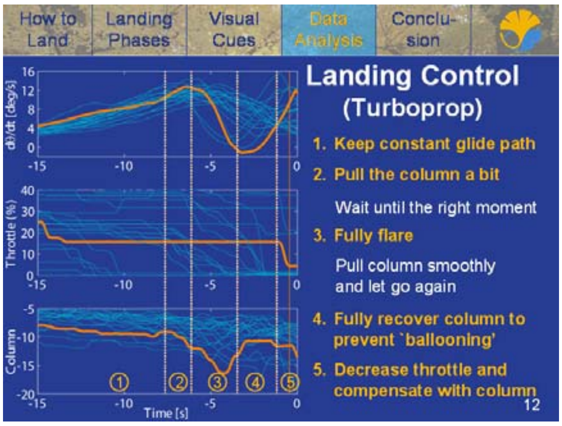

This is my idea of how the ΔRunwayAngle cue may be used to control the flare (timing)

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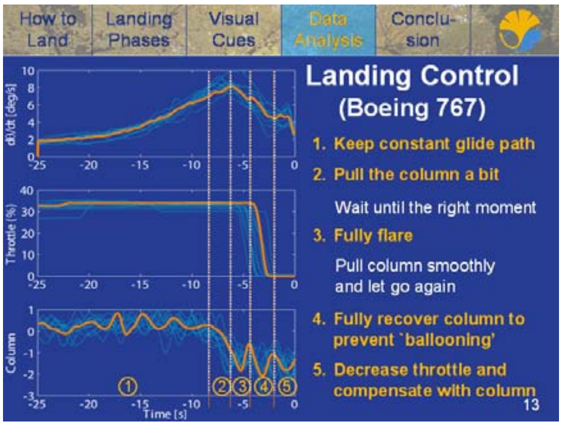

This is my idea of how the ΔRunwayAngle cue may be used to control the flare (timing)
You can see that the graphs are quite different from the turbo-prop case, but we can still recognize the same phases

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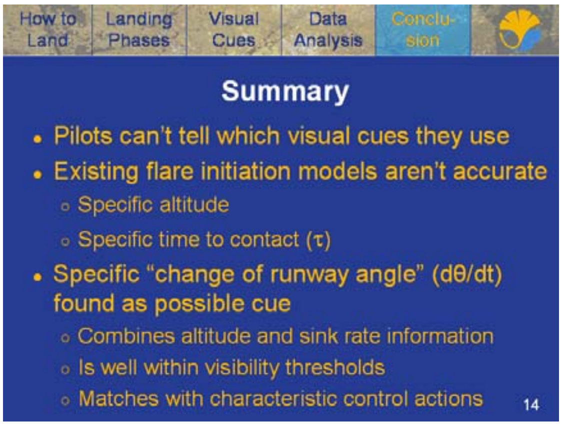

Like car driving, the way to land an aircraft cannot be put into words easily. To find out what is happening (subconsciously) in a pilot's brain, I obtained visual cue and control data from real and simulated landings

The existing hypotheses for flare timing did not match the data. A new cue has been suggested: the change of runway angle

It has been shown that this cue contains the necessary information (altitude, sink rate), it is visible for the pilot, and it matches the control data

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