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Optical Information in Landing Scenes

Walter W. Johnson
NASA Ames Research Center

ABSTRACT

During landing, the visual scene contains optical information about speed, altitude, glideslope, and track that is useful for the maintenance of spatial orientation and awareness. This information, embedded in the structure and transformations of the optical patterns, may be globally, regionally, or locally available. Global changes occur everywhere in the visual field during landing and include such information as flow rate acceleration due to changing speed and/or altitude. Regional changes occur within a more restricted area and include such information as horizon line motion due to aircraft pitching and rolling. Locally available changes are the most restricted and include such information as changes in runway form ratios due to changing glideslopes. Thus, within partially or fully synthetic displays, or within sensor-driven displays, preservation of flow rate and horizon motion information requires a minimum of knowledge about the details of the airport layout, while runway outlines do require much more knowledge of the layout. All may be important, however, and these, as well as other sources of optical information, can provide a pilot with his most natural framework for maintaining orientation.

Optical Information Analysis

Properties of Optical Information

- *Optical Patterns* - Structure and transformations of the optical geometry
- *Optic Regions* - Where the relationship can be viewed (Elevation & Azimuth)
- *Information Content* - Flight path properties (e.g. speed, closure rate, sink rate) that covary with changes in optical patterns
- *Ecological Constraints* - Restrictions under which the optical information analysis holds (e.g. flat level earth)

Applications of Information Analysis

- **Airport/Vertiport Design - Layout of landing surfaces, surface markings, and approach lighting**
- **Display Design - Determination of important format and content considerations**

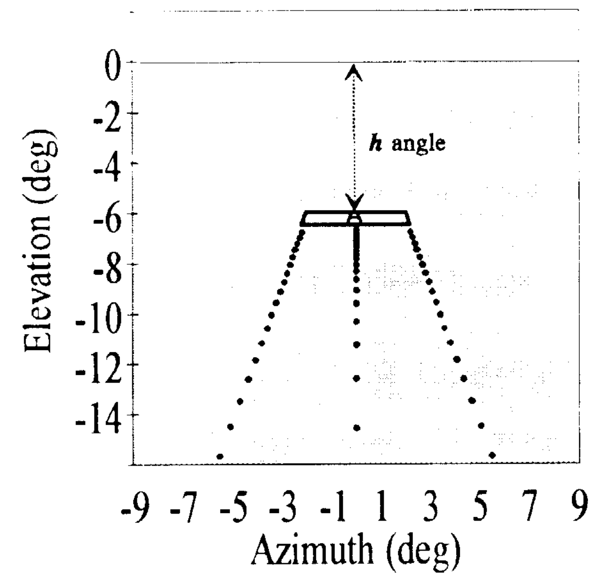
Information for Glideslope

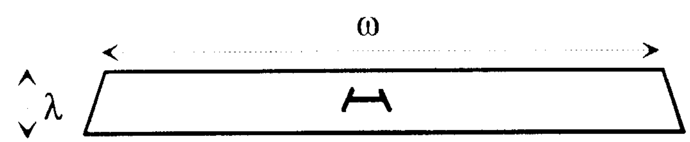
$$\alpha = Glideslope$$

$$\alpha = tan^{-1} \frac{z}{x}$$

$$\alpha = h$$

$$\alpha \approx \frac{W}{L} \bullet \frac{\lambda}{\omega}$$





Form Ratio =λ/ω

Constraints

h angle : correct horizon

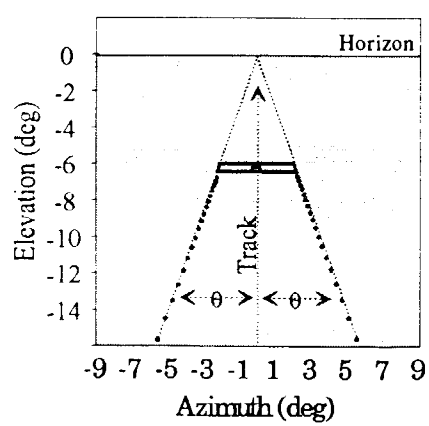
Form Ratio : Experience with pad dimensions

Optical Splay Rate

Splay Rate = $\dot{\theta} = \frac{\dot{h}}{h} \cdot \sin\theta \cdot \cos\theta$

θ = Angle between track vector and location on the ground, h = height above ground

Splay rate is globally modified by, and is useful for controlling, sink rate scaled in altitude units. It specifies rate of closure, or time to contact, with the ground.



All locations along paths parallel to the track vector have the same splay angle and splay rate.

Optical Flow Rate

$$\left(\frac{\dot{s}}{h}\right)\cdot sin^2\beta\cdot\sqrt{\left(\left(sin^2\alpha\cdot csc^2\beta+cos^2\alpha\right)\cdot cos^2\gamma+cot^2\beta\cdot sin^2\gamma-cos\alpha\cdot cot\beta\cdot sin\gamma\cdot cos\gamma\right)}$$

a = azimuth, b = elevation, g = glideangle, $\dot{s}$ = path speed, h = height above ground

Optical flow rate, as defined above, is the angular speed of optical elements associated with points on a level ground plane. Flow rate is globally modified as a function of path speed scaled in altitude units, and is therefore useful for controlling this parameter.

Optical Edge Rate

$$\frac{\dot{x}}{size}$$

$\dot{x}$ = ground speed, size = size/spacing of salient ground objects

Optical edge rate is the rate (frequency) with which optical discontinuities pass across an optical region or location. Edge rate is a function of groundspeed scaled in terms of the size or spacing of salient ground objects, and therefore useful for controlling this parameter.

Relative Optical Expansion Rate (Tau)

$$\frac{\dot{\theta}}{\theta} \approx \frac{\dot{s}}{r}$$

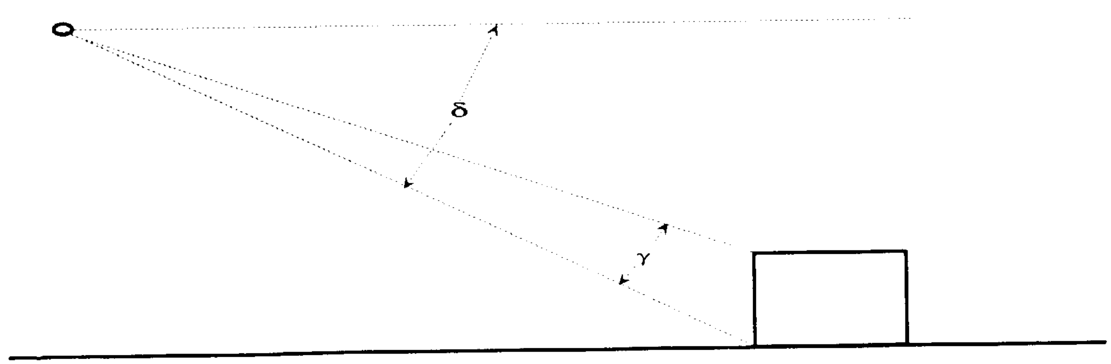
θ = Optical (angular) size of object being approached, $\dot{s}$ = path speed, r = range to the object

The relative optical expansion rate is a function of path speed and range to the object being approached, and is the relative (%/s) rate at which the angular size is changing. The inverse of this parameter is the projected time to arrival (tau). Therefore this is useful for controlling these quantities.

Information for Altitude

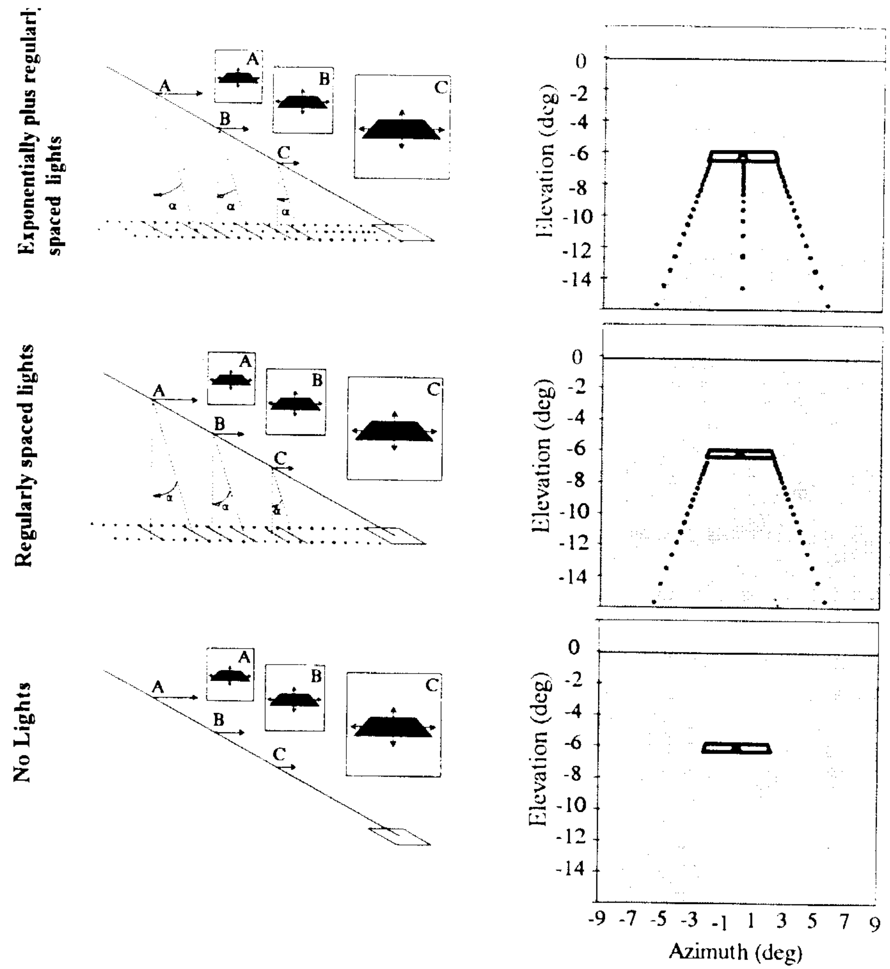
Horizon ratio $R = \gamma/\delta$

Horizon ratio is the ratio of the optical height of an object to the optical separation of the object base from the horizon. The horizon ratio is a function of the observer altitude and the object height, and approximates height above ground scaled in object height units.



Constraints
Correct Horizon

VMS Approach Lighting Study



Near & Far Optic Flow Rate - Path speed/Altitude
Optic Edge Rate - Groundspeed, GroundSpeed/Range
Optical Expansion Rate - Path Speed/Range
Near & Far Optic Splay - Sink Rate/Altitude
h angle - Glideslope
Form Ratio - Glideslope

Near & Far Optic Flow Rate - Path speed/Altitude
Optic Edge Rate - Groundspeed
Optical Expansion Rate - Path Speed/Range
Near & Far Optic Splay - Sink Rate/Altitude
h angle - Glideslope
Form Ratio - Glideslope

Far Optic Flow Rate - Path speed/Altitude
Optical Expansion Rate - Path Speed/Range
Far Optic Splay - Sink Rate/Altitude
h angle - Glideslope
Form Ratio - Glideslope

VI. IMAGE EVALUATION AND METRICS