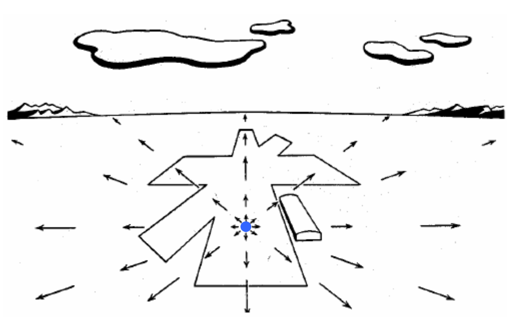
Analysis of Motion

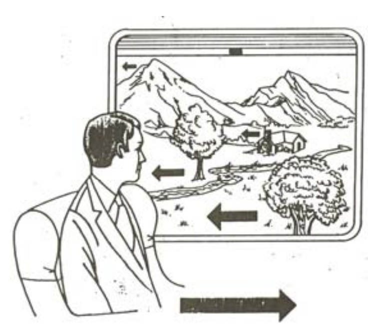
Recovering observer motion

CS332 Visual Processing
Department of Computer Science
Wellesley College

Recovering 3D observer motion & layout



FOE: focus of expansion



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Application: Automated driving systems

DARPA Urban Challenge

Observer motion problem

From image motion, compute:

- Observer translation

  $(T_x\ T_y\ T_z)$

- Observer rotation

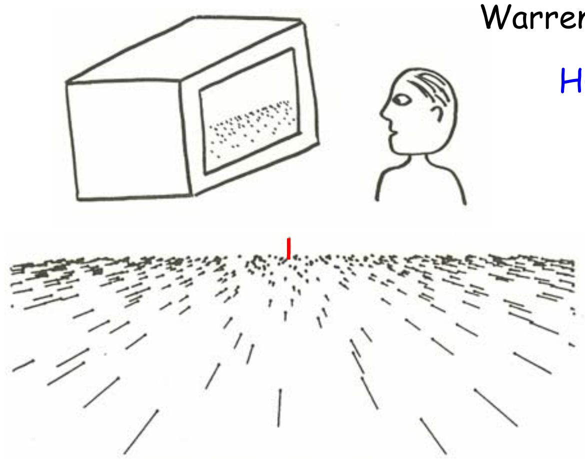
  $(R_x\ R_y\ R_z)$

- Depth at every location

  $Z(x,y)$

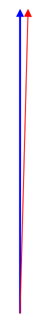
Human perception of heading

Warren & colleagues



Human accuracy:

1° - 2° visual arc



bird's eye view

Observer heading to the left or right of target on horizon?

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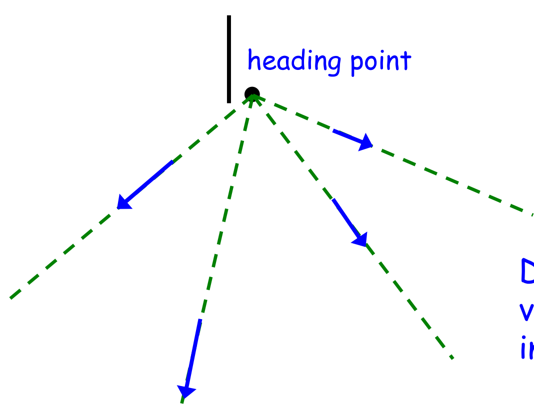
Observer just translates toward FOE



Directions of velocity vectors intersect at FOE

But… simple strategy doesn't work if observer also rotates

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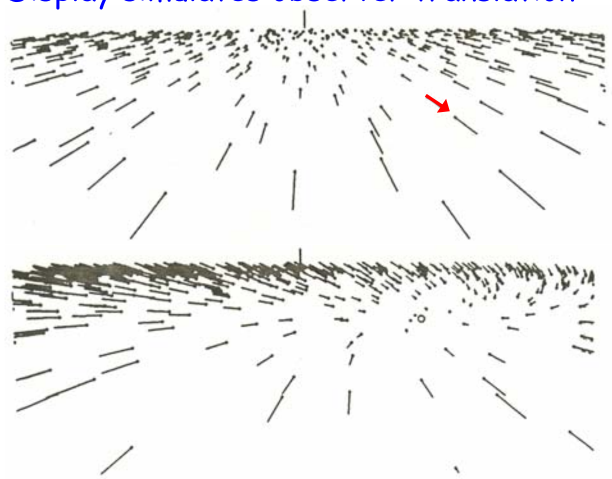
Observer Translation + Rotation

Display simulates observer translation



Observer rotates their eyes

Display simulates translation + rotation

Still recover heading with high accuracy

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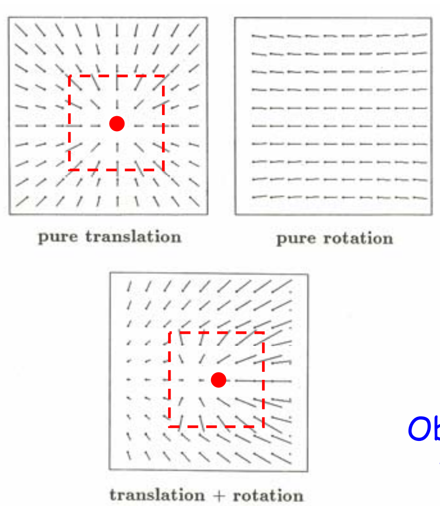
Observer motion problem, revisited



From image motion, compute:

- Observer translation

  $(T_x\ T_y\ T_z)$

- Observer rotation

  $(R_x\ R_y\ R_z)$

- Depth at every location

  $Z(x,y)$

Observer undergoes both translation + rotation

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Equations of observer motion

Translation	Rotation	Depth
(T_x, T_y, T_z)	(R_x, R_y, R_z)	$Z(x,y)$

$$V_x = (-T_x + xT_z)/Z + R_x xy - R_y(x^2+1) + R_z y$$

$$V_y = (-T_y + yT_z)/Z + R_x(y^2+1) - R_y xy - R_z x$$

$(-T_x + xT_z)/Z$ and $(-T_y + yT_z)/Z$ → Translational Component

$R_x xy - R_y(x^2+1) + R_z y$ and $R_x(y^2+1) - R_y xy - R_z x$ → Rotational Component

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Translational component of velocity

$$V_x = (-T_x + xT_z)/Z$$

$$V_y = (-T_y + yT_z)/Z$$

Where is the FOE?

x = y =

Example 1: $T_x = T_y = 0$ $T_z = 1$ $Z = 10$ everywhere

V_x = ______ V_y = ______

Sketch the velocity field

Example 2: $T_x = T_y = 2$ $T_z = 1$ $Z = 10$ everywhere

V_x = ______ V_y = ______

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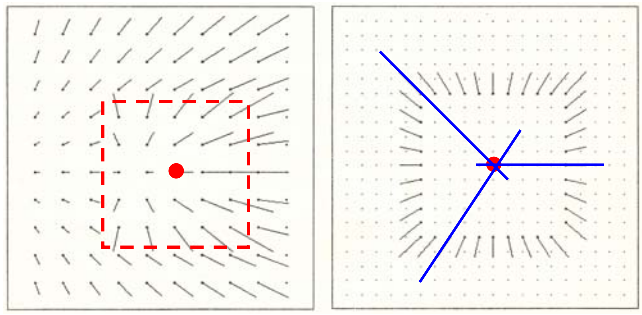
Longuet-Higgins & Prazdny



- Along a depth discontinuity, *velocity differences* depend only on observer translation
- Velocity differences point to the focus of expansion

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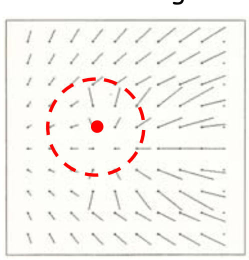
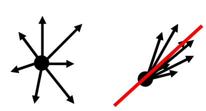
Rieger & Lawton's algorithm

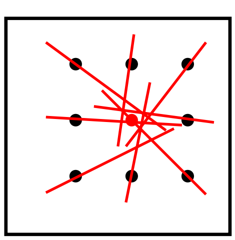
- At each image location, compute distribution of velocity differences within neighborhood



Appearance of sample distributions:



- Find points with strongly oriented distribution, compute dominant direction



- Compute focus of expansion from intersection of dominant directions

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