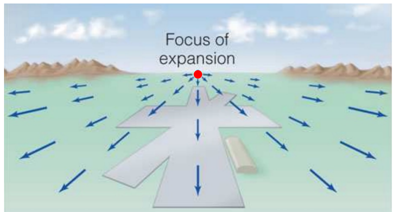
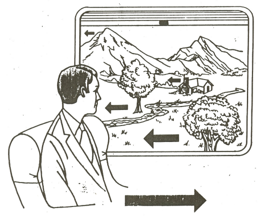
Recovering 3D observer motion & layout





FOE: focus of expansion

https://www.youtube.com/watch?v=m80b6esRpaQ

1

Application: Automated driving systems

DARPA Grand Challenge

https://www.wired.com/story/darpa-grand-urban-challenge-self-driving-car/

2

Observer motion problem

velocity field

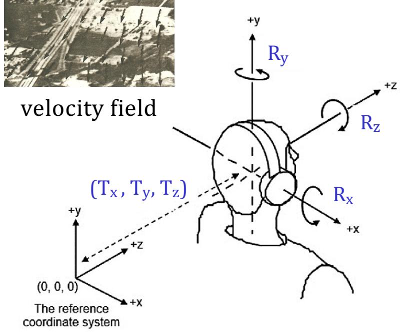
From image velocity field, compute:

- observer translation

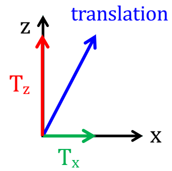
  $(T_x\ T_y\ T_z)$
- observer rotation

  $(R_x\ R_y\ R_z)$
- depth at each location

  $Z(x, y)$

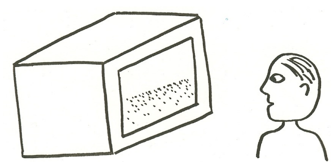


bird's eye view:



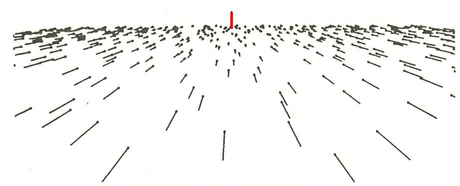
3

Human perception of heading



Warren & colleagues

Human accuracy:
1° - 2° visual arc



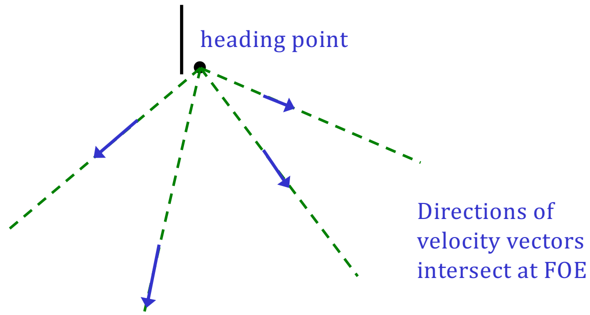
bird's eye view

~ 2°

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

4

Observer just translates toward FOE

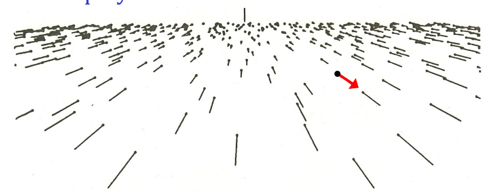


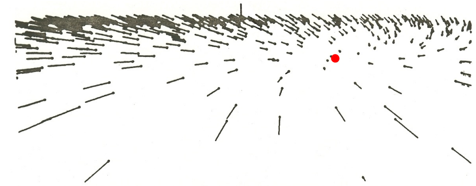
But… simple strategy doesn't work if observer also rotates

5

Observer Translation + Rotation

display simulates observer translation

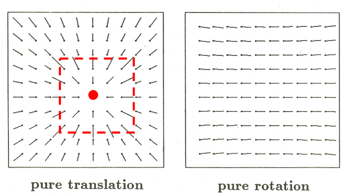


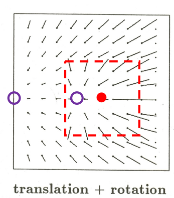


Still recover heading with high accuracy!

6

Observer motion problem, revisited





From image motion, compute:

- Observer translation

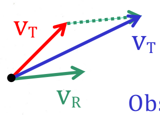
  $(T_x\ T_y\ T_z)$

- Observer rotation

  $(R_x\ R_y\ R_z)$

- Depth at each location

  Z(x,y)



Observer undergoes ***both*** translation + rotation

7

Equations of observer motion

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

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

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

Translational Component (first term) — Rotational Component (remaining terms)

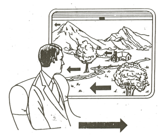
8

Translational component of motion

$$V_x(x,y) = \frac{-T_x + xT_z}{Z(x,y)}$$

$$V_y(x,y) = \frac{-T_y + yT_z}{Z(x,y)}$$

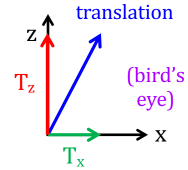
- V_x, V_y, Z depend on position (x,y)
- Note Z(x,y) in the *denominator*



- V_x, V_y depend on *ratios:* T_x/Z T_y/Z T_z/Z

(e.g. doubling both observer speed & depth gives the same velocity field)

- Where is the FOE? $x = T_x/T_z$ $y = T_y/T_z$



9

Translational component of velocity

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

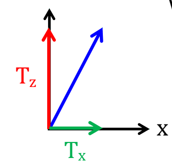
$V_y = (-T_y + yT_z)/Z$

Where is the FOE?

x = y =

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

V_x = ______ V_y = ______



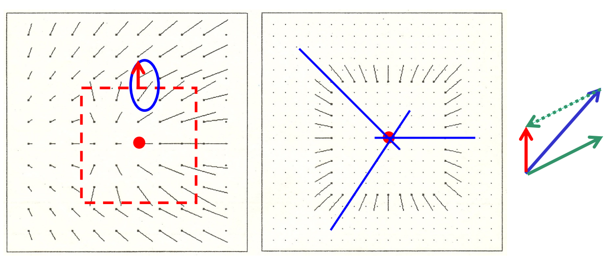
Sketch the velocity field

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

V_x = ______ V_y = ______

10

Longuet-Higgins & Prazdny

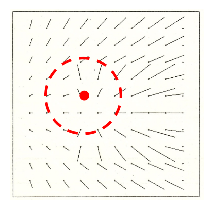


- Along a depth discontinuity, *velocity differences* depend only on observer translation
- Velocity differences point to the focus of expansion

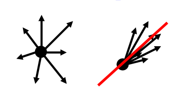
11

Rieger & Lawton's algorithm

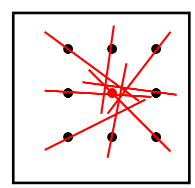
(1) At each image location, compute distribution of velocity differences within neighborhood



Appearance of sample distributions:



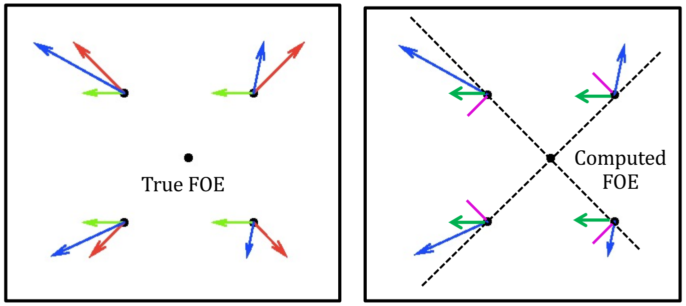
(2) Find points with strongly oriented distribution, compute dominant direction



(3) Compute focus of expansion from intersection of dominant directions

12

Recovering the observer's rotation



Velocity component due to observer's translation
Velocity component due to observer's rotation
Final velocity at each location

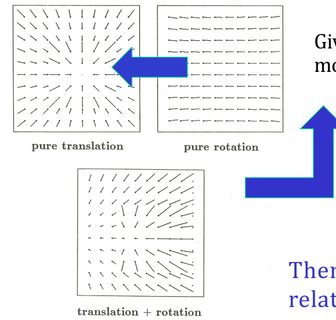
Computed FOE → *translational field lines*

Velocity perpendicular to field lines must be due to observer's rotation!

Find (R_x, R_y, R_z) that ***best explains*** the motion perpendicular to the field lines

13

Finally, recovering 3D layout



Given (R_x, R_y, R_z), compute image motions due to rotation…

… then subtract motions due to rotation, to obtain the image motions due to the observer's translation alone

Then, how can we compute the relative depth of surfaces?

What are we assuming about objects in the scene?

When is this assumption violated?

14