Lecture 4:
Koenderink and Van Doorn 1991
Affine structure from motion

COMP 30025J

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First up, what's Affine/Structure/Motion mean in this paper.

- In this paper its important to understand what the author means by affine transformations , structure and motion
- Any transformations that preserves relationships between points, lines and most importantly including preserving parallel relationships.
- Structure in this paper is defined as a rigid body and that in any views to be processed that the structure has stayed the same.
- Thus motion refers only to the camera position changing and nothing else.

Euclid (aside just to remind you)

- AXIOMS
- "To draw a straight line from any point to any point."
- "To produce a finite straight line continuously in a straight line."
- "To describe a circle with any centre and distance."
- "That all right angles are equal to one another."
- "That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles." (Parallel lines)

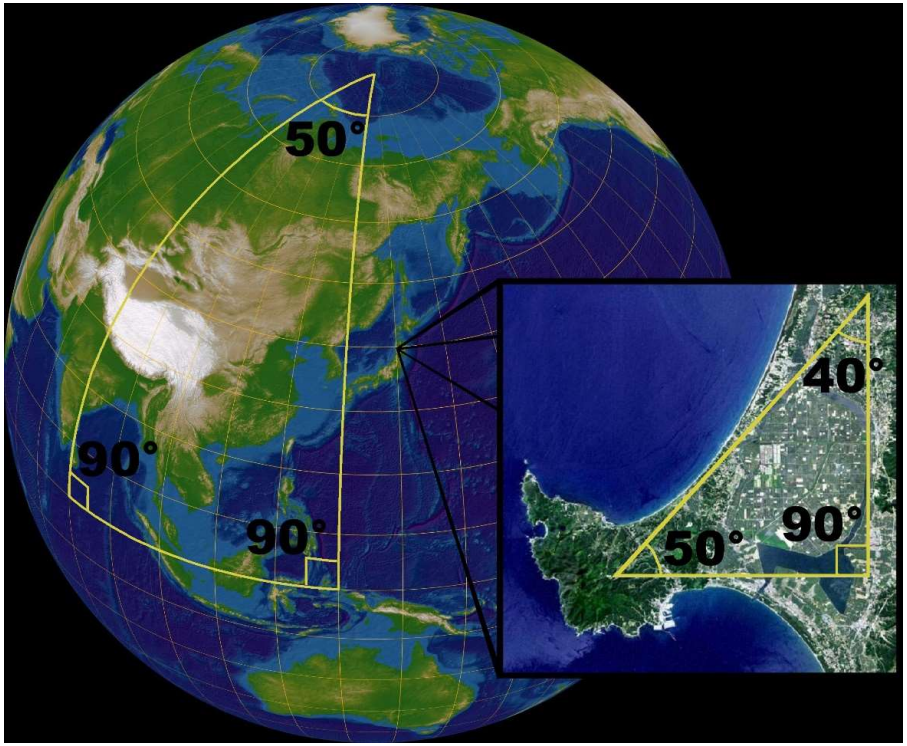
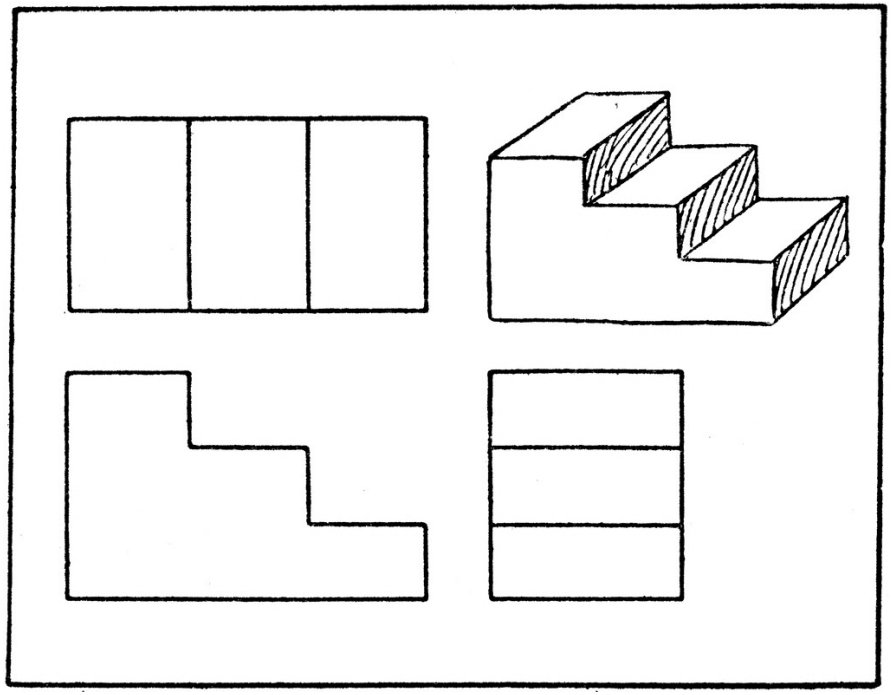


Image from Wikipedia for non Euclidean geometry)

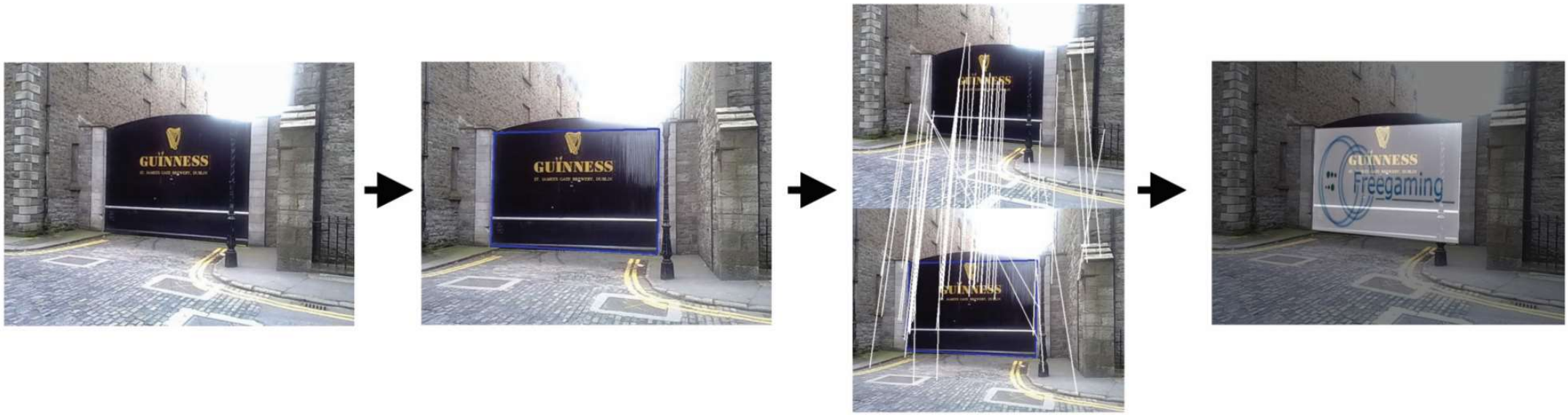
Orthographic projection

- Representing a three-dimensional object in <u>two dimensions</u>



Thomas E. French and Carl L. Svensen *Mechanical Drawing For High Schools* (New York: McGraw-Hill Book Company, Inc. , 1919) 29

Features / Fiducial points



Abstract

- Paper will discuss the so called Structure from motion problem
- It’s a theory paper so we may read it differently than others
- The paper will discuss the stages need to solve the problem , but admittedly it just will solve it for a specific set of axioms.
- The use of three views is need (the third being for calibration)

Breakdown of the paper

- Introduction
- Stratification of the structure from motion problem
- Affine Structure from motion theorem
- Numerical experiment
- Rigidity and the metric
- Three views

Introduction

- Vision behind the paper
- Story set out
- N views with M points
- Axioms
  - Identify given fiducial points in different views
  - Can use spherical trigonometry to get angles for this rays
  - Spatial configuration is a priori know to be rigid

Introduction (continued)

- Theorem
  - “given three distinct orthographic views of four non-coplanar points in a rigid configuration, the structure and motion compatible with the three views are uniquely determined”
  - When we think about this , technical drawing has always done this.
  - The paper will attempt to stratify the problem,
    - E.g Identify each stage needed

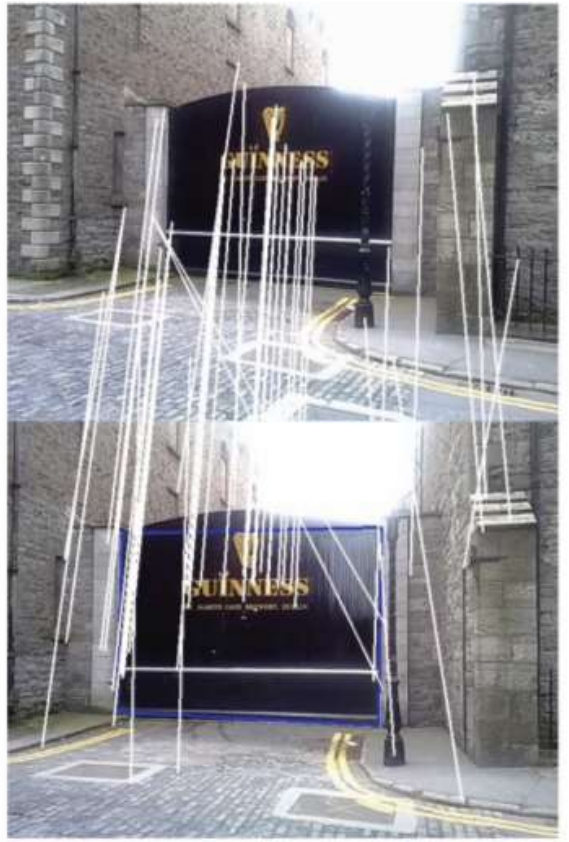
Stratification of the structure from motion problem

- Assuming parallel projection / Limited field of view with restricted depth range.
  - Parallel projection is a good approximation to central projection if the field of view is small/depth limited
  - Arbitrary smooth deformations are locally equivalent to affine transformations.

- Need to make sure that size significantly changes with depth
- Axis of rotation can be known , and you can work out scale and shear
  - This first stage is equivalent to the humans eye stereo vision system,

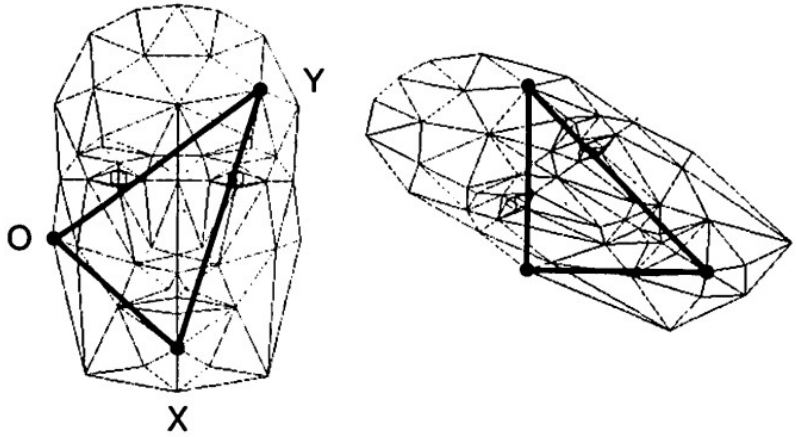
Affine Structure from motion theorem

- Point P in the plane OXY , then its affine coordinates have to be the same in both views if the spatial configuration was subjected to an arbitrary linear transformation.
- A third view can then be used to check, and it has the ability to falsify.



Numerical experiment

- Same as the previous section but demonstrating the concept using maths



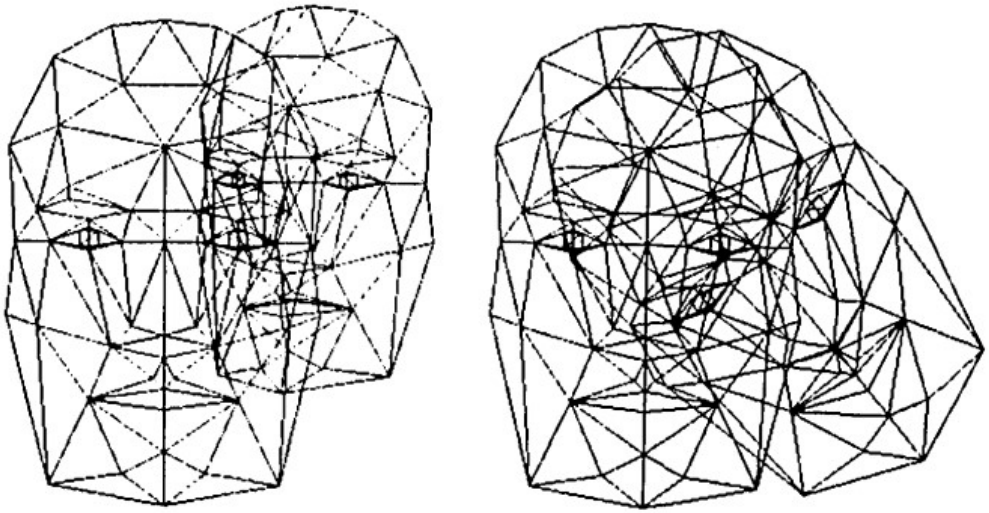


Fig. 1. Superposition of the 0th and 1st (left) and 1st and 2nd (right) views. Both figures contain one identical view (the 1st), a full frontal view of the triangulated face. The 0–1 transition is due to a rotation in space about the vertical (head shake) and a divergence; the 1–2 transition is due to a rotation about the horizontal (head nod) and a curl, or cyclorotation.

Numerical experiment

- Optical flow of the points
- This is very important idea now as its how the VIVE works

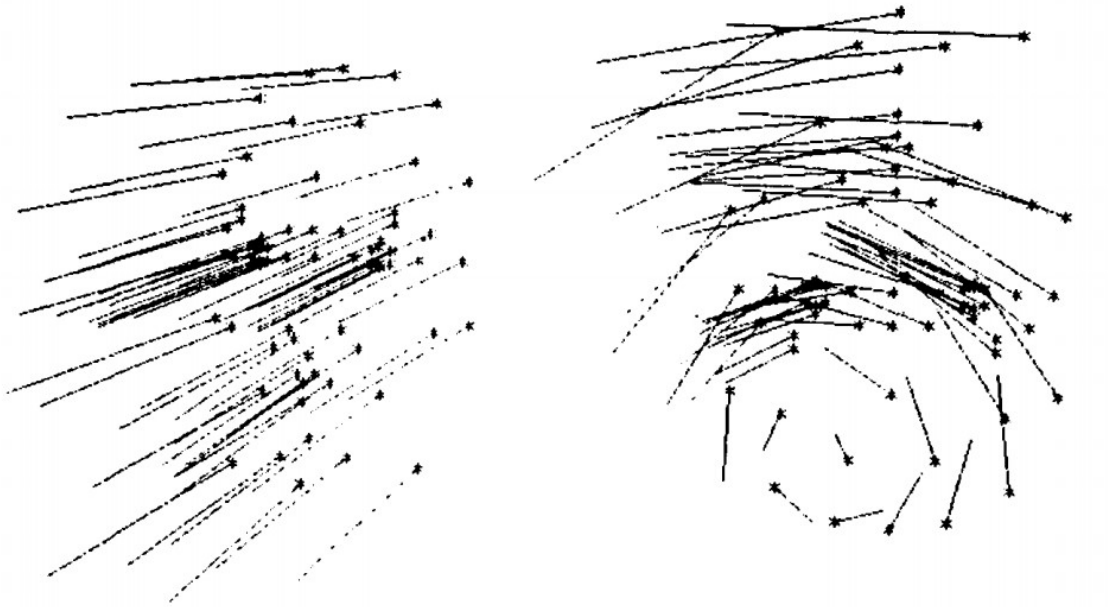
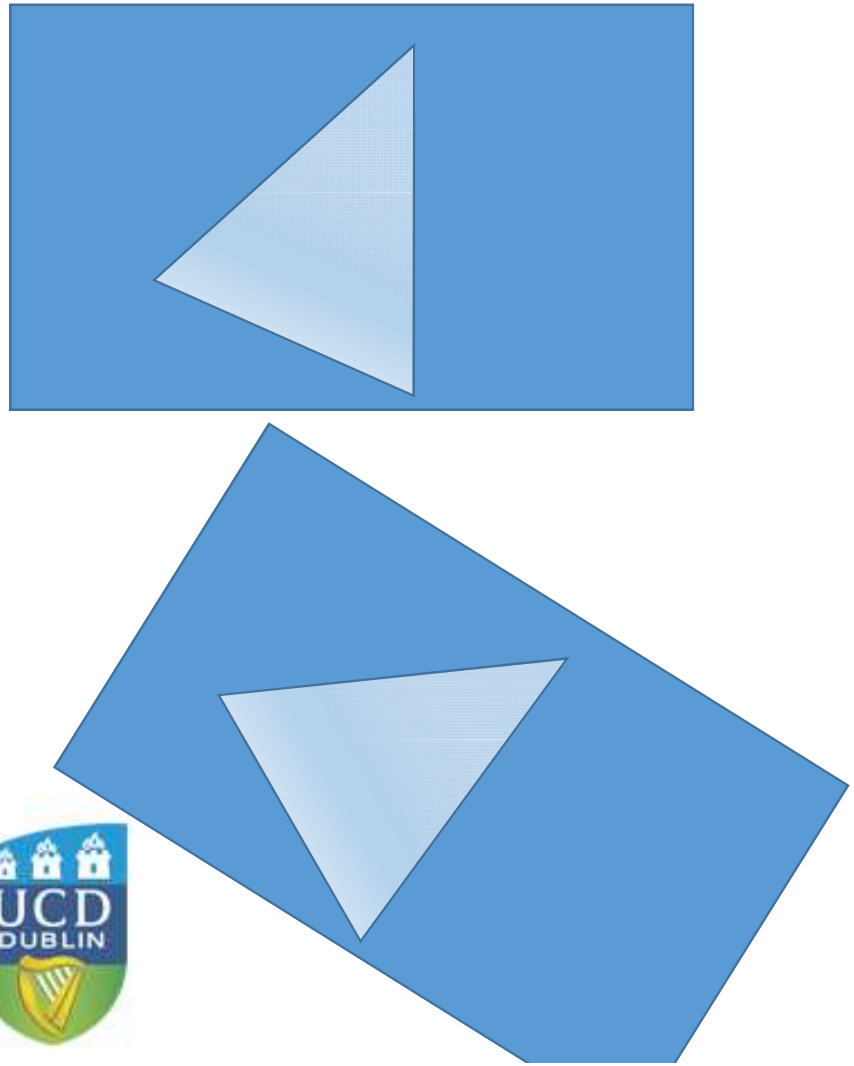


Fig. 3. Optical flow for the 0–1 (left) and 1–2 (right) transitions. Notice the strong divergence and curl.

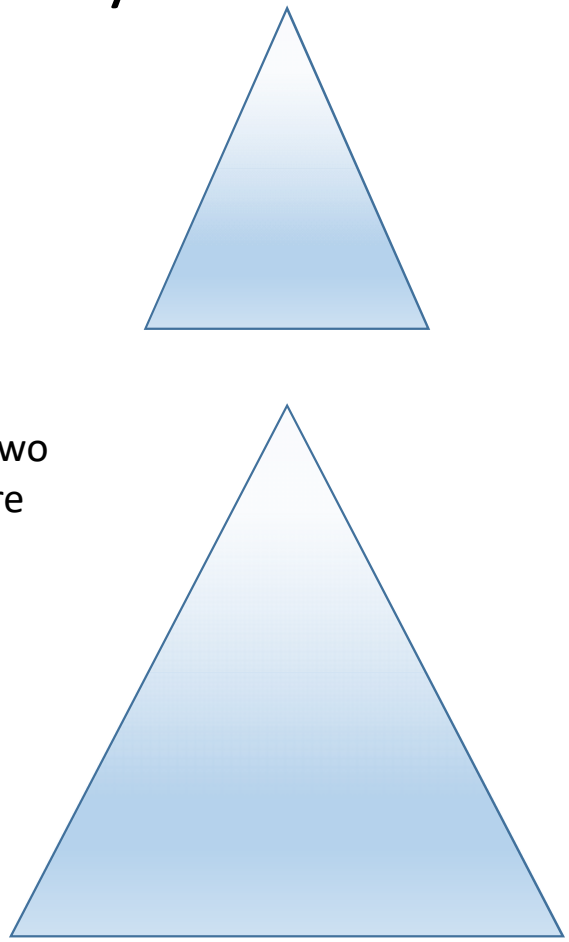
Rigidity and the metric



- This section is discussing how we calculate out our depth of relief by using the fact that you can decompose rotation into rotation in the image plane and a rotation about the axis in a frontoparallel plane.
- We find these rotation and then match up the points and the look for scale

Rigidity and the metric

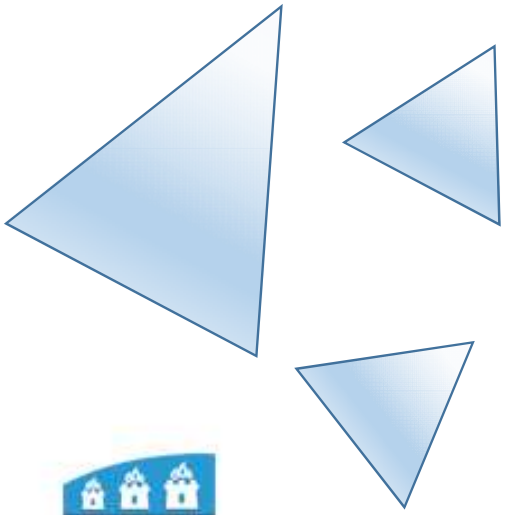
If we know enough about the image, we can rotate the image to get two images that are just scaled differently

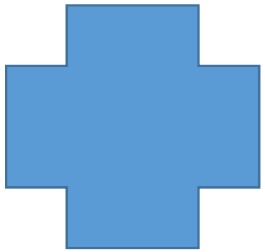


- It adds the Rigidity axiom as a requirement.
- For example If we have set of features we know is the same and two different view , one larger and one smaller
- This information can be am metric to establish differences in scale.

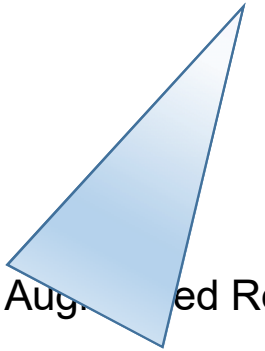
Three views

- Once all the axis's of rotations are accounted for, you are actually left with three views, that are reminiscent of taking a profile view to measure the orientation of the fiducial triangle and depth of relief .





Scaling factors = 3D Geometry



Conclusions

- First stage of the Solution
  - A small field of view
  - Smooth transformations in 3D space
  - Affine constructions in the visual field
- Second stage of the Solution
  - The transformation in 3D space is a isometry(Rigidity)
  - Metrical constructions in the visual field are allowed (we can get scale)
- This paper was just a theory paper, the computational power to do this on a large scale seemed prohibited , but now we can.

No recommend reading this week (still will be reading paper)

- Its time to start thinking about your project and essay
- Deadline wise , the sooner you submit a one page outline for both, the sooner you can get started
- I'll put a provisional deadline in Moodle for 7th October but I will be watching the Moodle during the break
- As with mobile projects, if I accept you outline , Ill mark it 100% , that's not a final grade , just to indicate that I'm happy with the submission and you can start working on it.

Next weeks paper

- This paper is another survey paper but goes into more detail about how tracking is achieved. You should see a bit of crossover with some of the other papers we have already covered. The main topic of the paper is tracking

- The paper is

"A Survey and Taxonomy of Location Systems for Ubiquitous Computing"

by Jeffrey Hightower and Gaetano Borriello from 2001