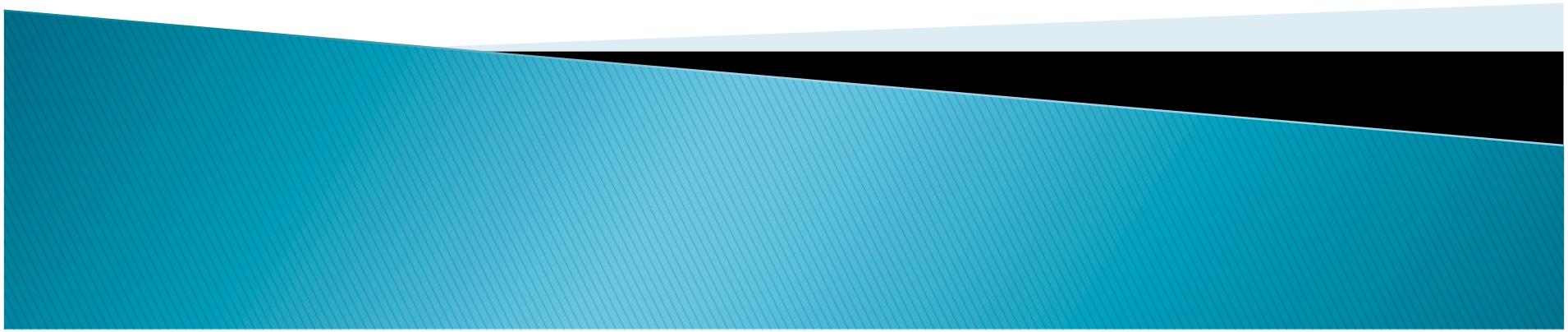
Three Camera Epipolar Geometry

Image Correspondence and Depth Recovery

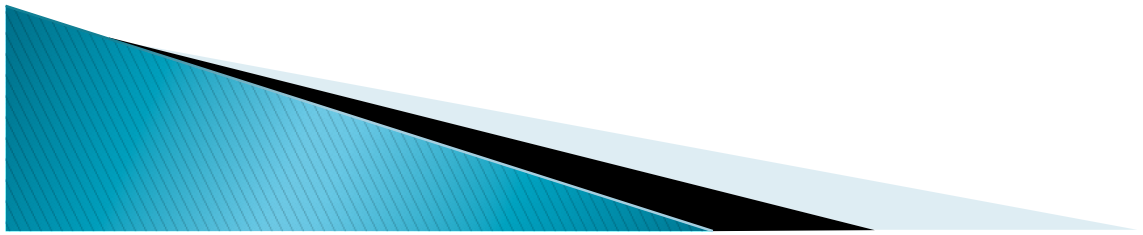
Gene Wang 4/26/2011



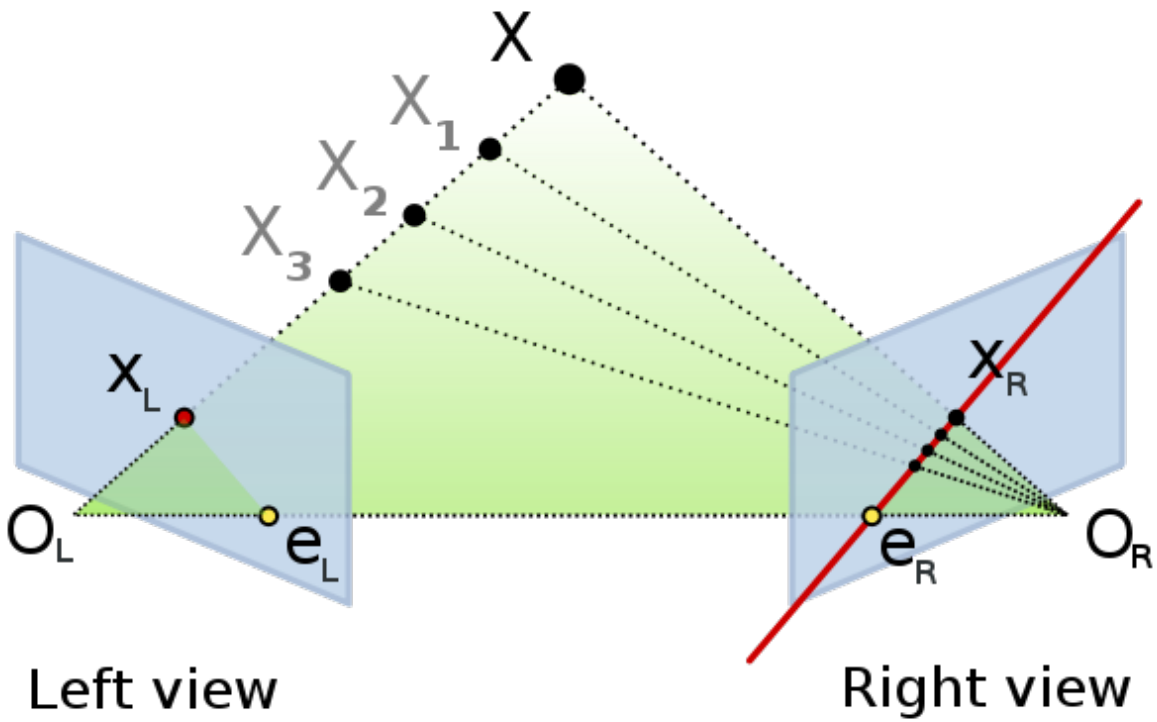
Problem Statement

- Stereopsis and epipolar geometry can be used to determine 3D point information from 2D images.

- Does adding a third camera give the system any more information for solving the correspondence problem and depth recovery?



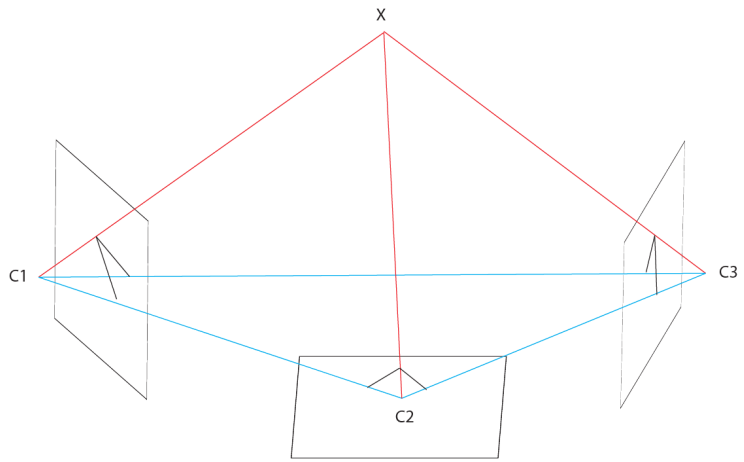
Review of Stereopsis



Source: http://en.wikipedia.org/wiki/File:Epipolar_geometry.svg

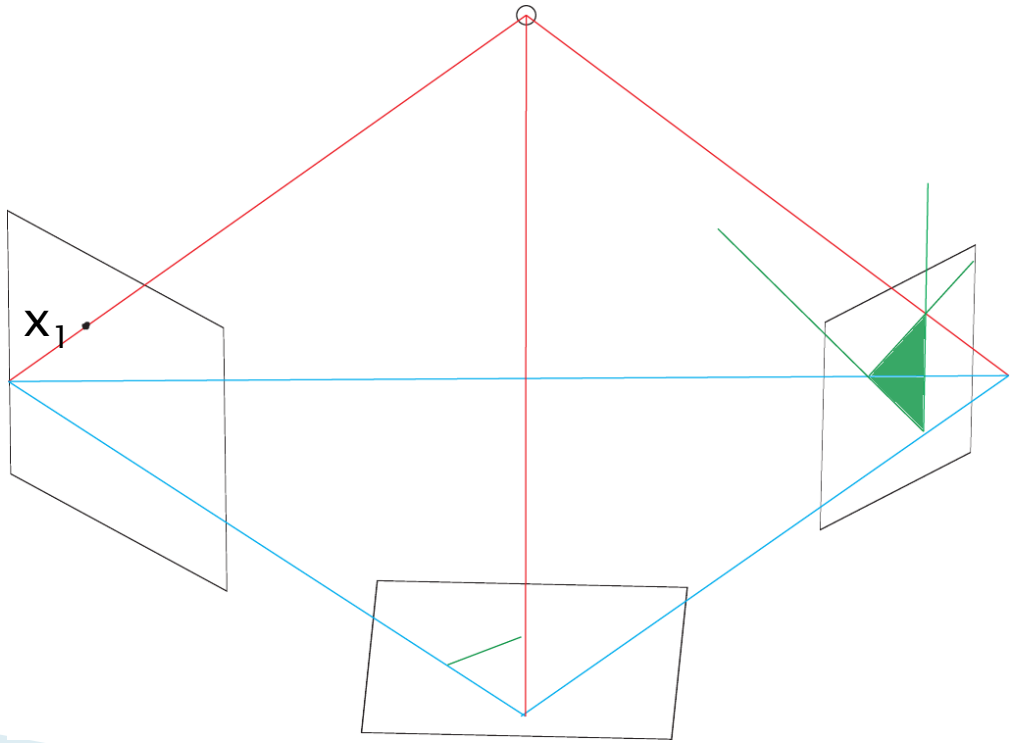
Trinocular Geometry

- Given three cameras with centers C_1, C_2, C_3.
- X, C_1, C_2, C_3 forms a triangular prism.
- The plane C_1C_2X and C_1C_3X intersects image 1 in a line.
- The two lines intersect at the projected point of X on image 1. (Likewise for images 2 and 3).



Correspondence Problem

- Given projected point x_1 on image 1, find the corresponding points on the other images.



Fundamental Matrix

- Given:
- Camera calibration matrices K_1, K_2
- Translational matrix $S(t)$
- Rotational matrix R
- Point x_1 in image 1

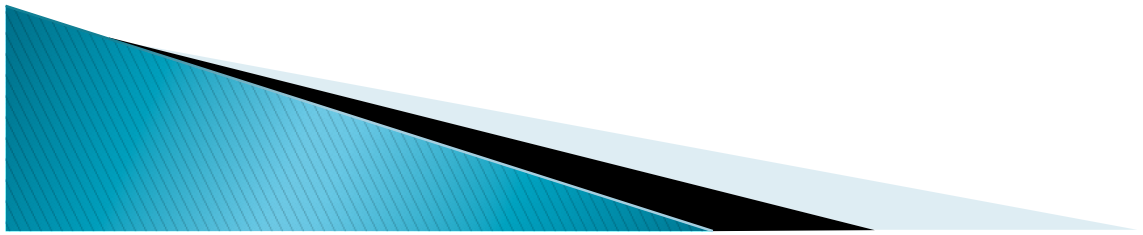
- Then: $x_1^T F e = 0$
- Where $F = (K_1^{-1})^T S(t) R^{-1} K_2^{-1}$
- Can be used to find a linear set of candidates for corresponding points in image 2.

Source: http://www.cse.buffalo.edu/courses/cse668/peter/lec/02.html

Correspondence Problem

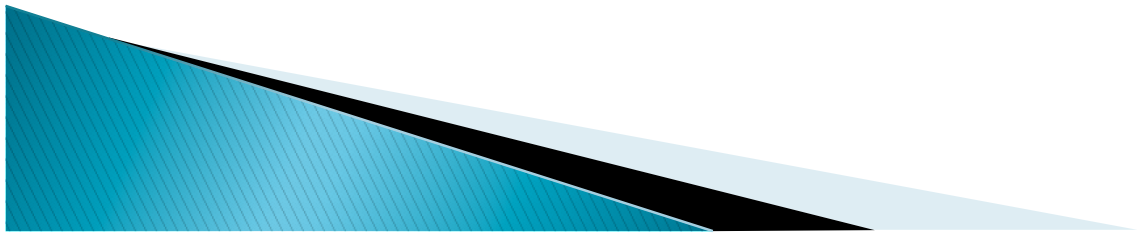
- By repeating the fundamental matrix calculation for camera 3, the correspondence problem can be done with 2 linear searches.

- However, this is simply repeating the two camera solution twice.

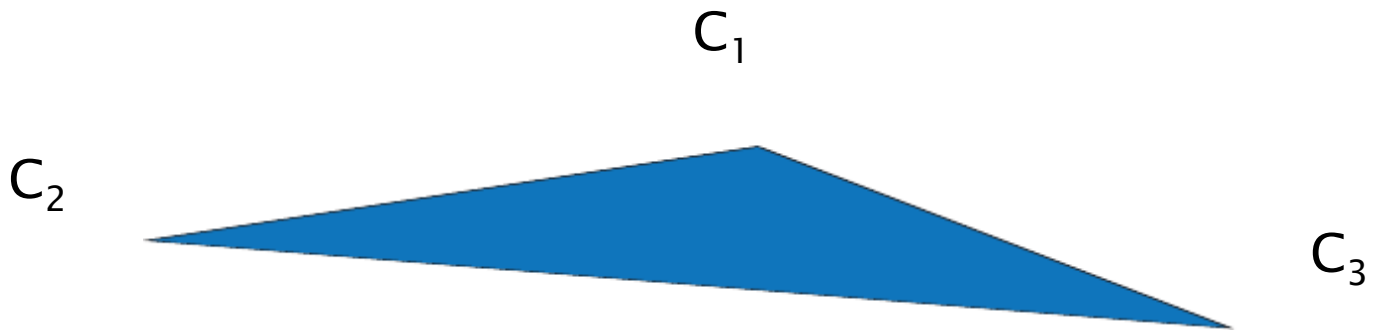


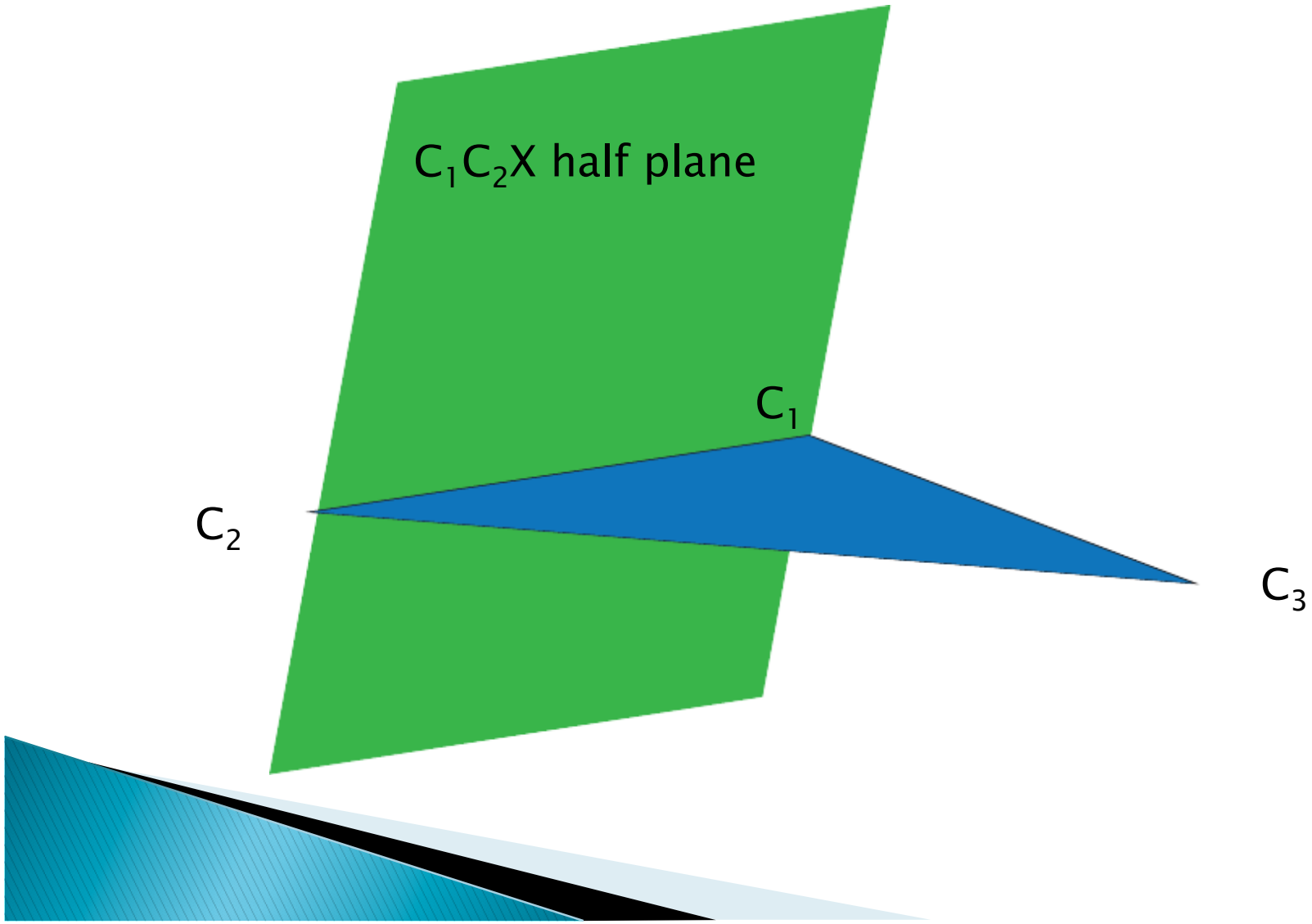
Using All Three Cameras

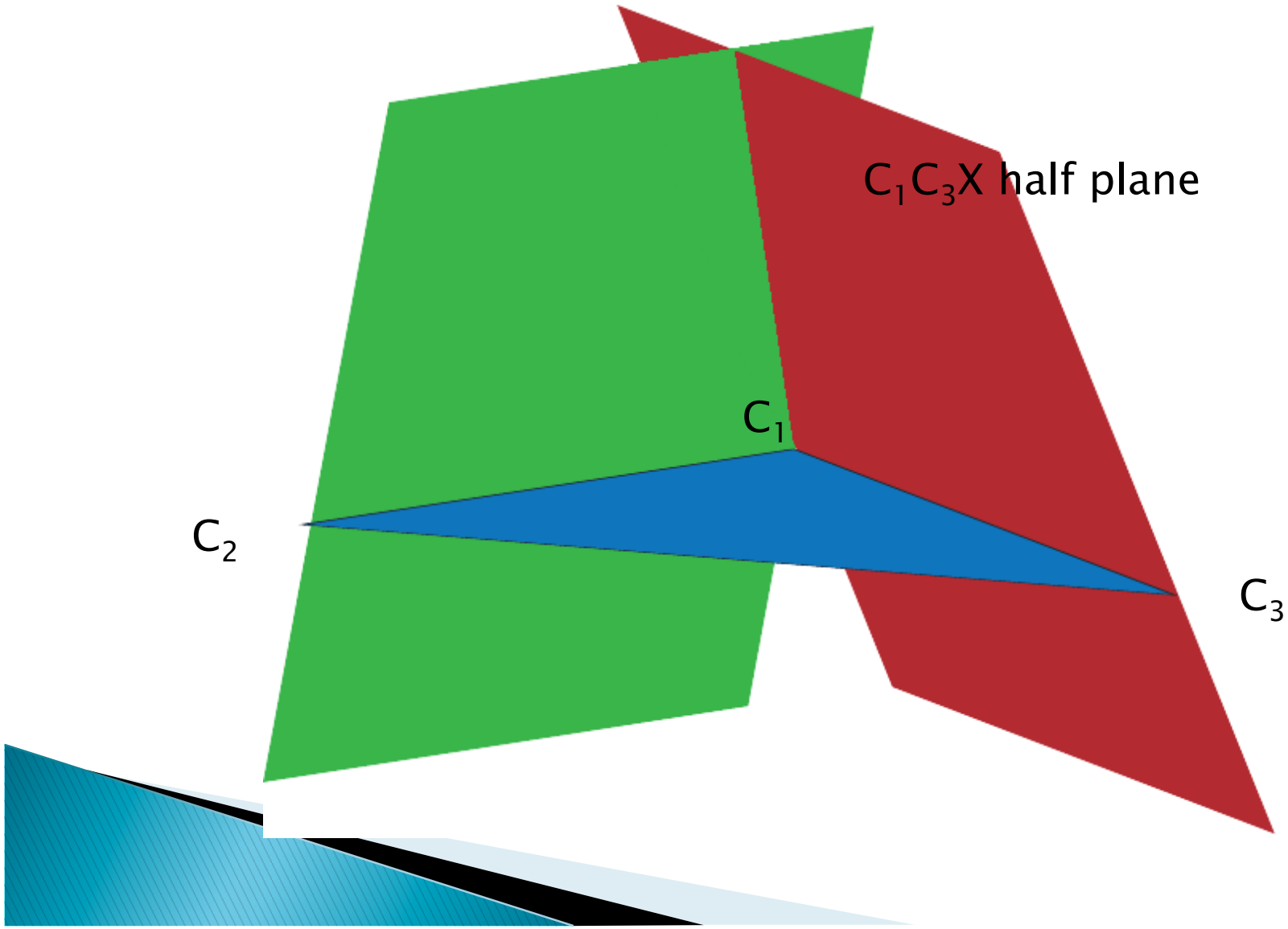
- With the same method, the projected point x_1 on image 1 will determine one epipolar line on each of the other images.

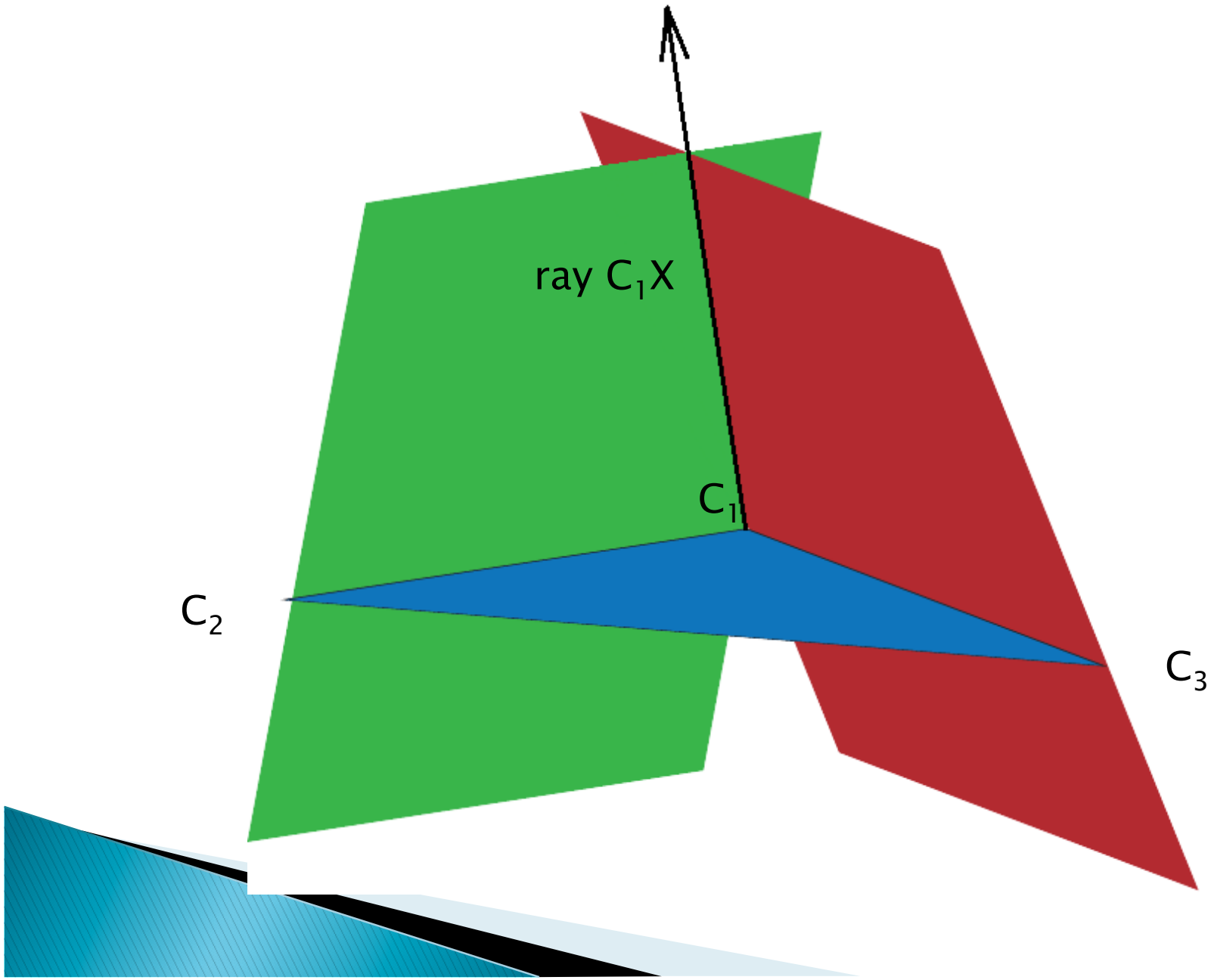


Camera base plane (analogous to the base line in stereopsis)

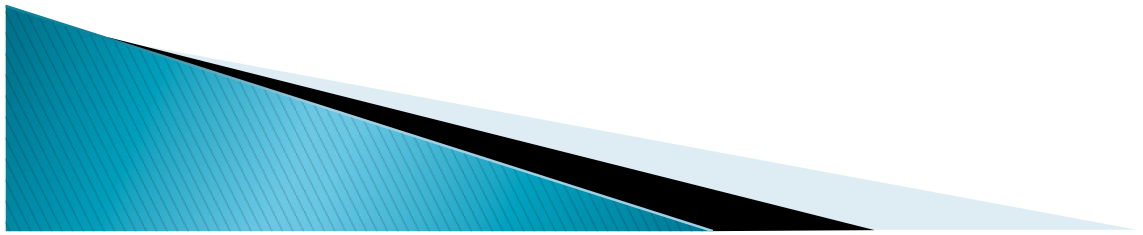



C_1C_2X half plane
C_1
C_2
C_3

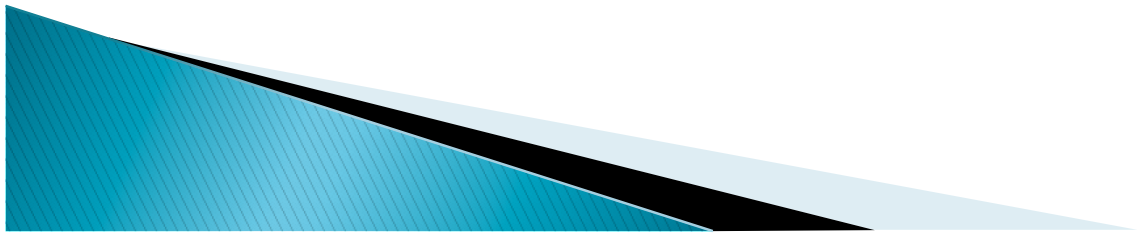

C_1C_3X half plane
C_1
C_2
C_3

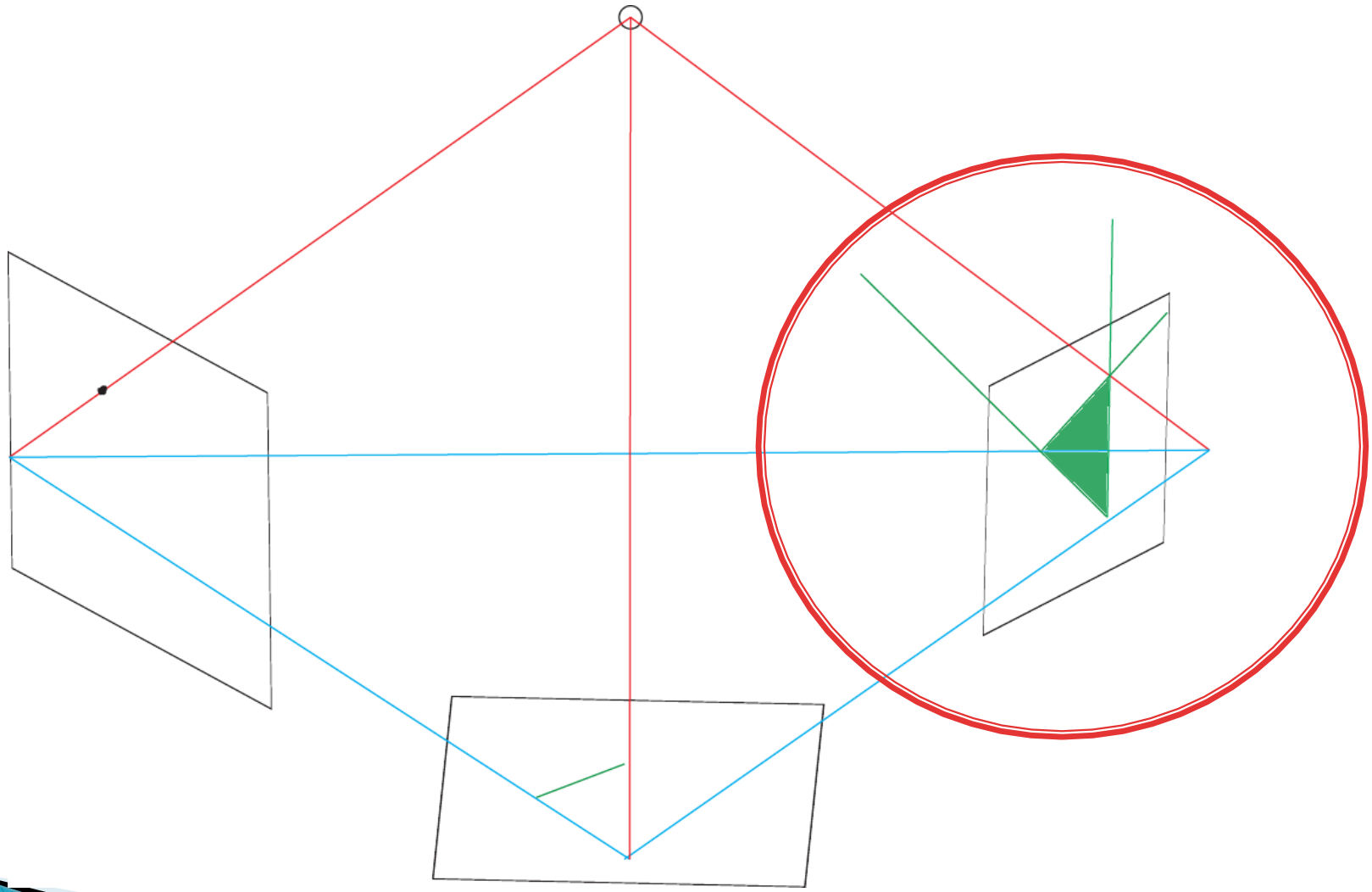

ray C_1X
C_1
C_2
C_3

- Using the epipolar lines in images 2 and 3, it's only possible to "undo" the projections and recover the ray C_1X
- Any possible new information must come from between cameras C_2 and C_3.

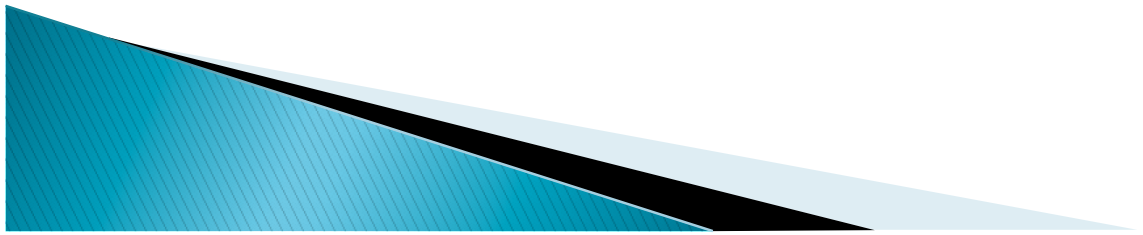


- Image 2 and 3 both contain 1 epipolar line.
- Each line represents a half plane in the world space.
- Projected back on to the other camera results in a region.



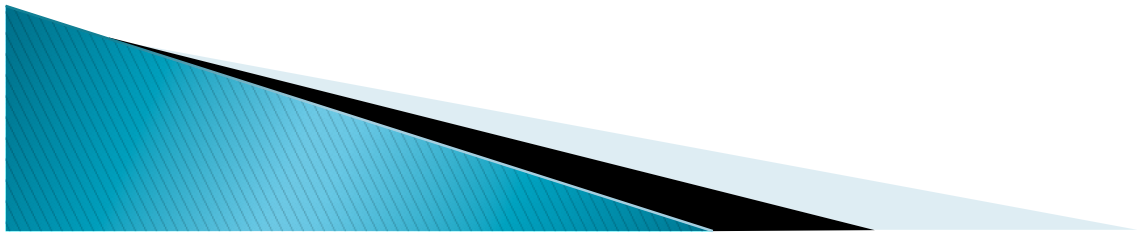


- So the information between cameras 2 and 3 is actually a 2D search range.
- It does not help in any way to improve the search range from the original epipolar line derived from image 1.



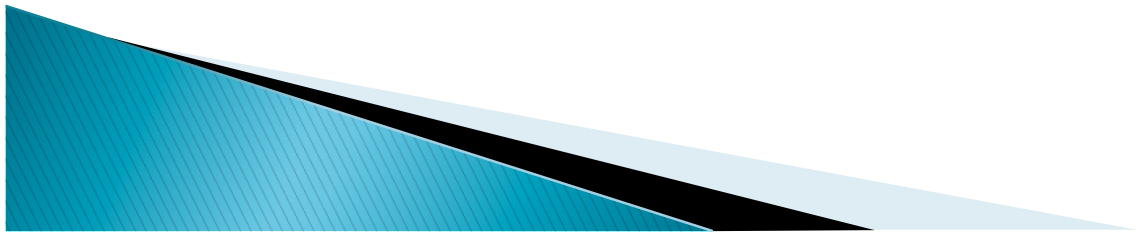
Depth Recovery

- Depth recovery is predicated on having completed image correspondence.
- Given two corresponding points and the camera calibration matrices, the world coordinates for any point X can be easily calculated.
- Using camera angles and triangulation.



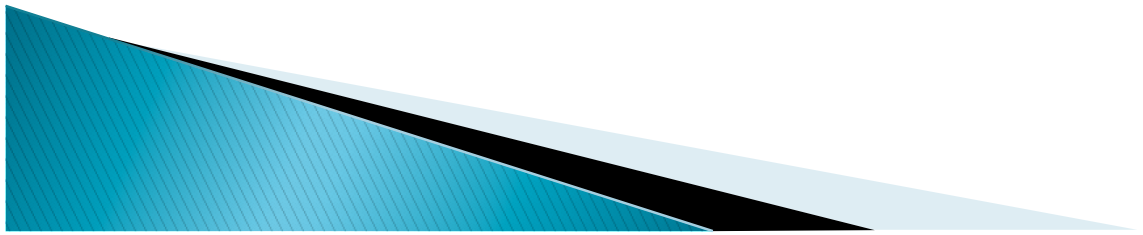
Practical Applications

- In real world situations, estimations and probability are involved.
- Having a trinocular system can reduce error and increase robustness.



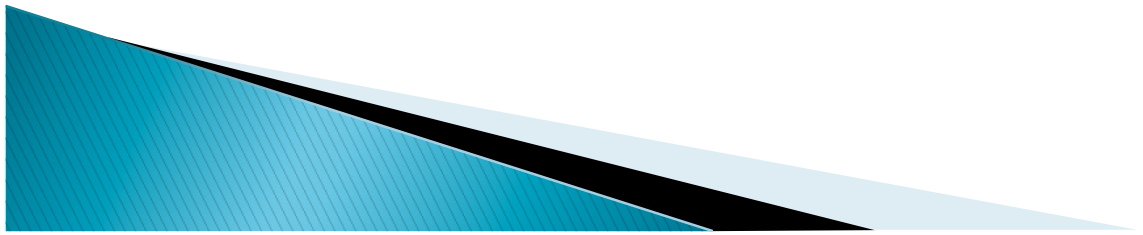
- Once a point is located in 3D space, its projection on any calibrated camera can be calculated.

- Error reduction can be done by calculating projection for the third camera using the other two for each camera and find the best match.



Additional Goals

- Testing and evaluating trade-off between extra correspondence calculations and error reduction.



Thank you