PURDUE ENGINEERING

Ch. 6 & 7 of the Course material

CE 59700: Digital Photogrammetric Systems

Lab1: Bundle Adjustment with Self Calibration (BASC)

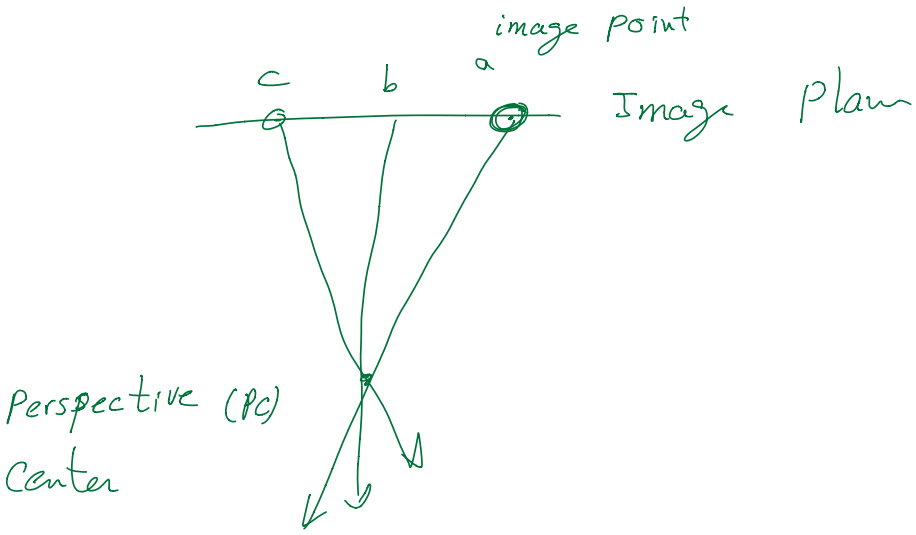
Distortion modeling & removal

Objectives

- Determine the camera's Interior Orientation Parameters (IOPs) using a bundle adjustment with self calibration procedure.

Photogrammetric (3D) Reconstruction

a) Reconstruct the camera geometry



output of (a) image bundle in the camera reference frame

+ location of PC w.r.t. image plane } IOPs
+ determine distortions if any

Lab #1

(b) Geo-referencing

position / orient the camera stations for every image in the object space

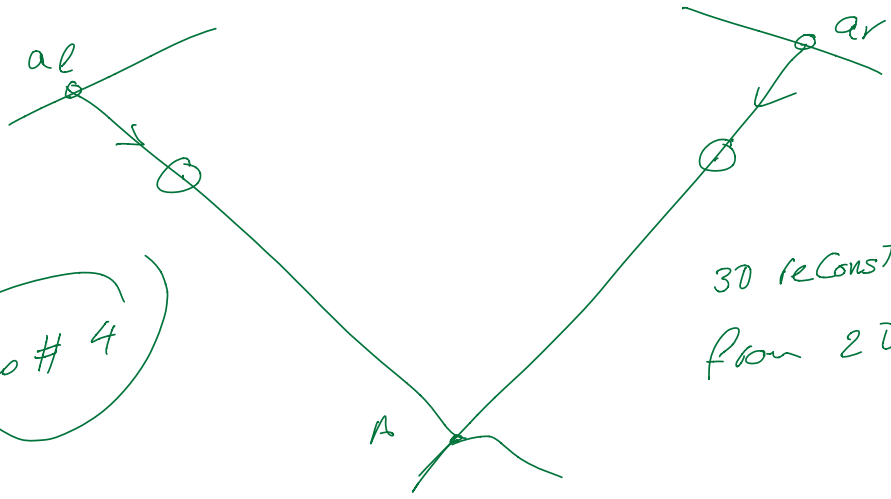
For each image ⟹ + position 3 parameters X_0, Y_0, Z_0

EOPs [+ orientation ω, ϕ, κ "rotation angles"

↑ Labs 2 & 3

Exterior orientation parameters for every image in our block

IOP & EOPs are property established e.g., stereo-par



Lab # 4

3D reconstruction from 2D Images

Lab # 1

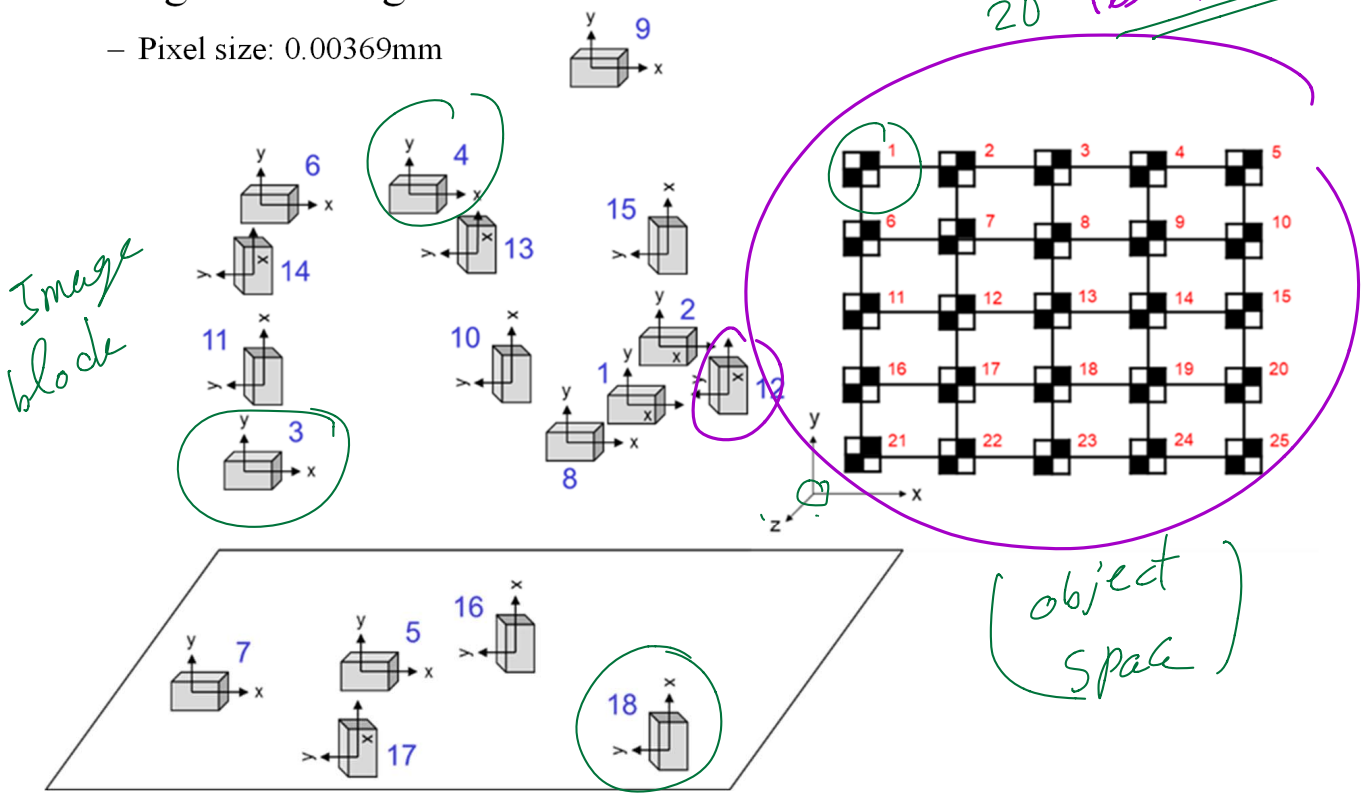
IOP, EOP, Intersection

Bundle Adjustment

BASC SW is given to You

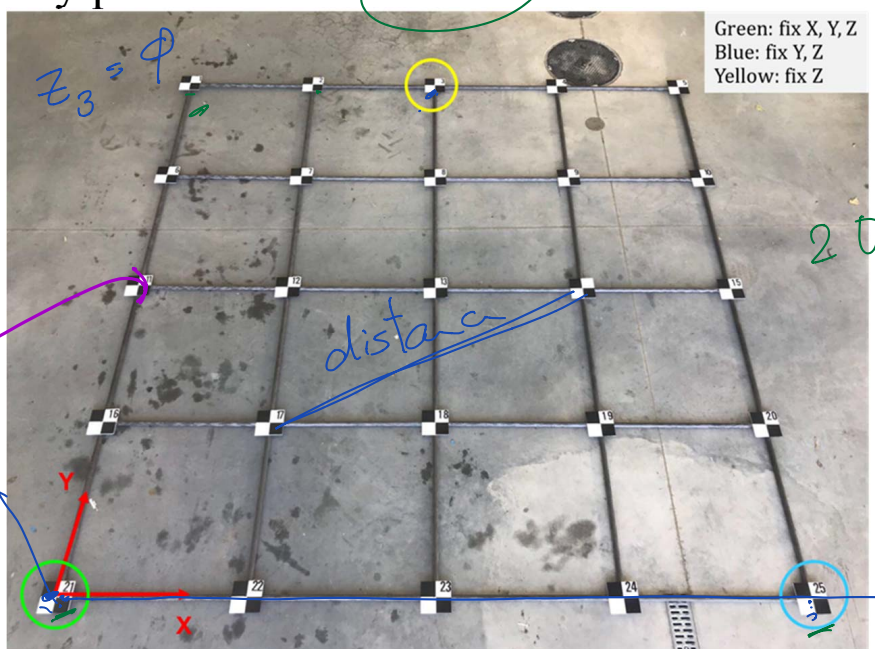
Given

- Eighteen images of a calibration test field
  - Pixel size: 0.00369mm



Given

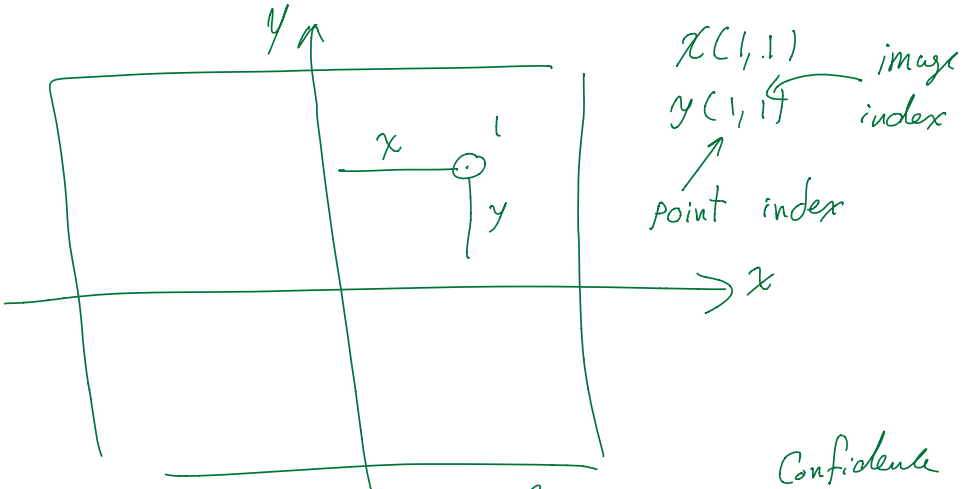
- Necessary parameters for datum definition



Fixed coordinates are shown.
Some distances have been also measured.

Image Coordinate measurement process

Lab #1: 18 images most of which cover the 25 targets in the test field.



ICF: Image Coordinate file

Confidence in this meas.

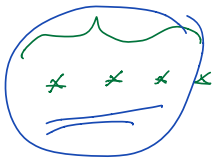


Image ID	Point ID	x	y
18 images	x 25 targets	=	=

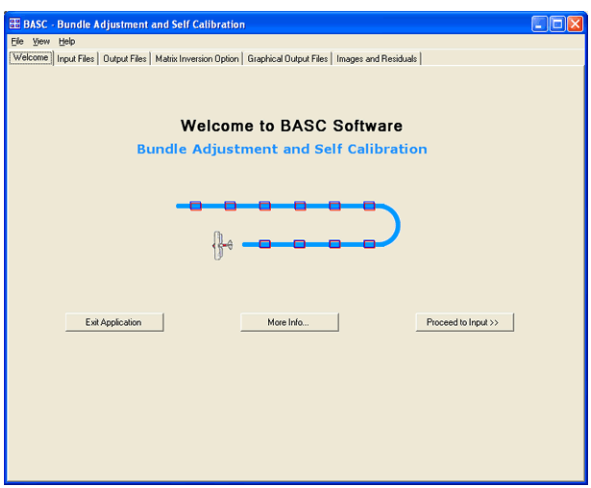
= 450 point meas.

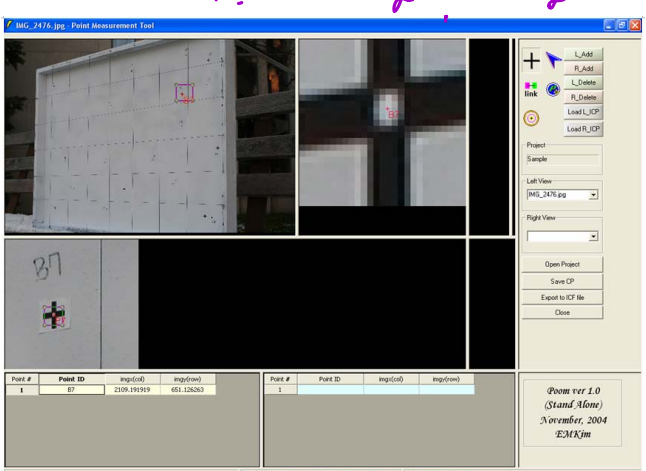
18 images

- 16 Images are given
- 2 Images for those, you need to use POOM ~ 50 targets to measure

Given

- Two Software Packages:
  - BASC (Bundle Adjustment with Self Calibration)
  - POOM (image measurement software)





BASC

Estimates

IOPs

EOPs

Ground Coordinates of the target

Key objective of this lab

BASC

observations ⇒ Least Squares Adjustment engine ⇒ unknowns

IOPs *.cam

EOPs *.ori

X,Y,Z of *.GCP object points

ICF

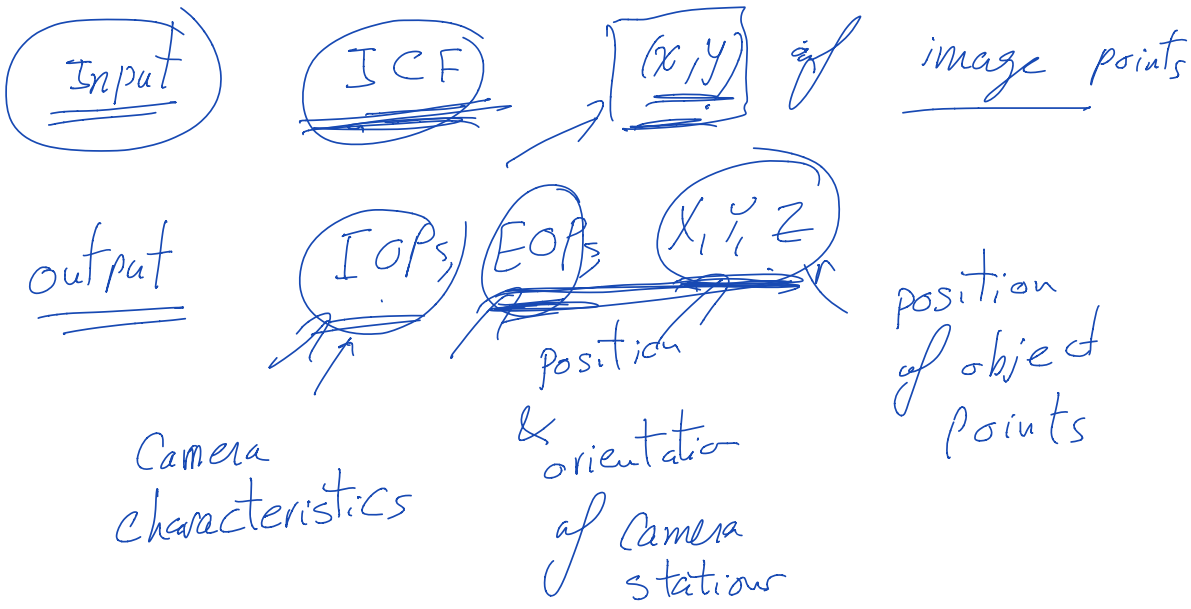
(x,y) of image points

Math. Model

Collinearity Eqs. ach. 7+

Non-Linear model

we need to provide the program with initial guess of the unknowns



Datum definition is missing

a) provide X, Y, Z for some points in your reference frame
→ indirect geo-referencing

b) Provide position / orientation inf. for some images
→ direct geo-referencing

GNSS / INS ⟹

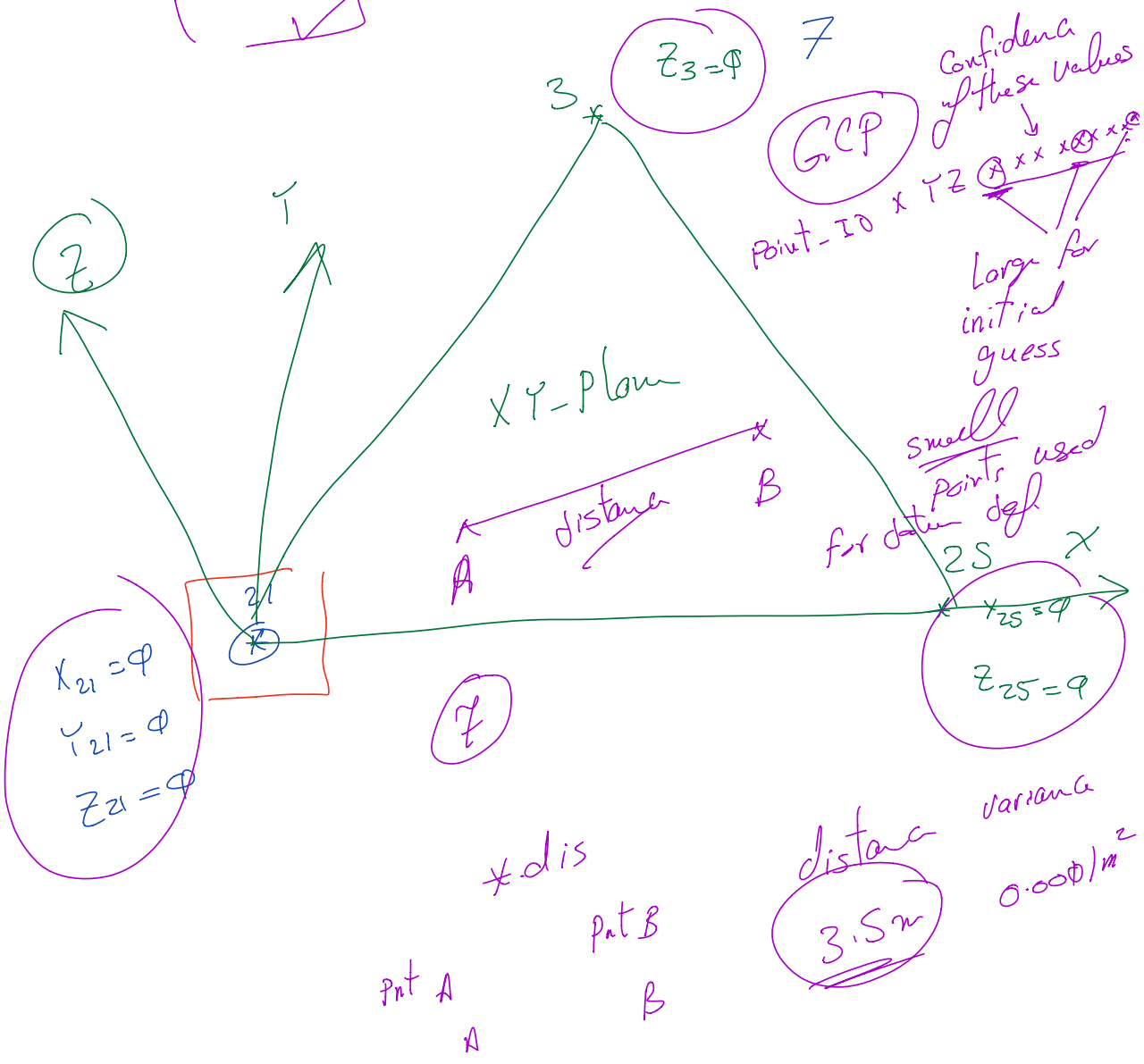
Datum definition

\+ origin of Coord. system — 3 parameters

\+ orientation of axes — 3 parameters

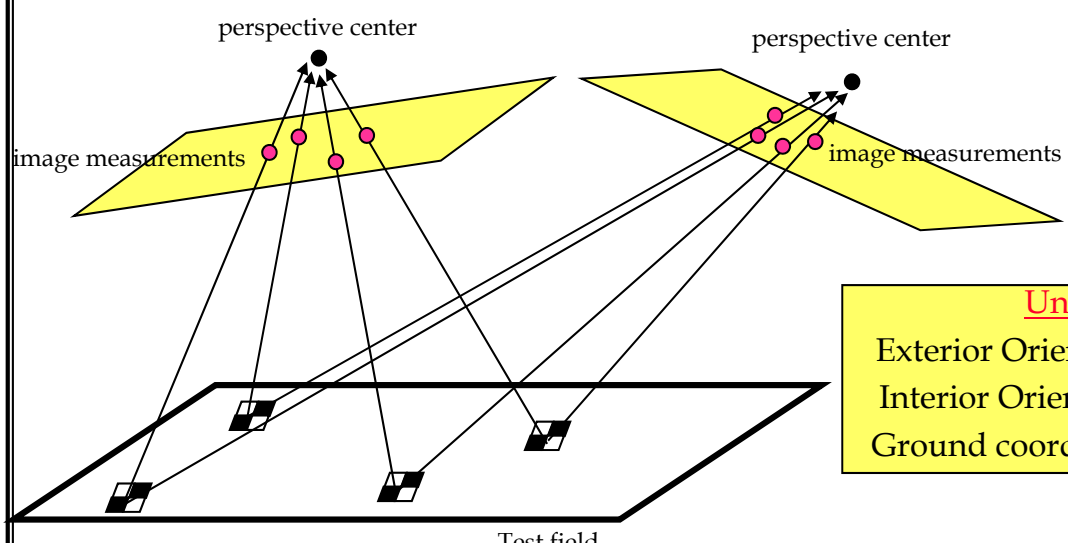
\+ scale — 1 parameter

7



Camera Calibration

- In addition to the Exterior Orientation Parameters (EOPs) of all images, the camera characteristics and ground coordinates of tie points are also considered as unknowns.



Unknowns:
Exterior Orientation Parameters
Interior Orientation Parameters
Ground coordinates of tie points

Step1: Image Measurement

1. Image measurements for sixteen images are provided.

2. Measure pixel coordinates in the remaining two images (**65_09_20180803.jpg & 65_17_20180803.jpg**) using **POOM** and convert the pixel coordinates to the image coordinate system.

Step2: Prepare Input Files and Run BASC

1. Prepare the input files for BASC
   - Project file (*.prj)
   - Image coordinate file (*.icf)
   - Ground control points file (*.gcp)
   - Camera file (*.cam)
   - Orientation file (*.ori)
   - Distance file (*.dis)

2. Run BASC

2. Analyze the results

Step2: Sample Files

1. Project file (*.prj)

!noiter>>maxSigma>>minCov>>minCov2>>gpsAvail>>insAvail>>distanceAvail;

25	1.0e-8	1.0e+4	1.0e-7	0	0	1

Step2: Sample Files

2. Image coordinate file (*.icf)

Image ID	Point ID	x (mm)	y (mm)	weight matrix			
GOPRO0001.jpg	11	-6.57477	6.24022	1.0	0.0	0.0	1.0
GOPRO0001.jpg	13	-2.66084	5.63411	1.0	0.0	0.0	1.0
GOPRO0001.jpg	12	-4.54673	5.58374	1.0	0.0	0.0	1.0
GOPRO0001.jpg	14	-0.83127	5.49290	1.0	0.0	0.0	1.0
GOPRO0001.jpg	16	2.43619	5.29403	1.0	0.0	0.0	1.0

weight matrix for SCF $\Rightarrow \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

You need to add the image coordinate measurements for the remaining two images.

Step2: Sample Files

3. Ground control points file (*.gcp)

Point ID	X	Y	Z	variance covariance matrix								
11	0.045	-0.003	0.511	1.00E-09	0	0	0	1.00E-09	0	0	0	1.00E-09
12	0.140	0.000	0.497	1.00E+10	0	0	0	1.00E+10	0	0	0	1.00E+10
13	0.239	0.000	0.504	1.00E+10	0	0	0	1.00E+10	0	0	0	1.00E+10
14	0.341	-0.001	0.499	1.00E-09	0	0	0	1.00E-09	0	0	0	1.00E-09
15	0.452	0.000	0.501	1.00E+10	0	0	0	1.00E+10	0	0	0	1.00E+10
16	0.560	0.000	0.508	1.00E+10	0	0	0	1.00E+10	0	0	0	1.00E+10

Control point

Tie point

Step2: Sample Files

4. Camera file (*.cam)

!CameraID	type	xp	yp	c
GOPRO	FRAME	0.0	0.0	3.0

!Dispersion matrix of xp,yp,c (3x3)

25.0	0.0	0.0
0.0	25.0	0.0
0.0	0.0	25.0

!No. of distortion parameters

7

0.0	0.0	0.0	0.0	0.0	0.0	0.0

!Dispersion matrix of distortion parameters (7x7)

1.0e-9	0.0	0.0	0.0	0.0	0.0	0.0
0.0	1.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	1.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	1.0e-9

!GPS offsets: dx, dy, dz

0.0	0.0	0.0

!Dispersion matrix of GPS offsets (3x3)

1E-12	0.0	0.0
0.0	1E-12	0.0
0.0	0.0	1E-12

Step2: Sample Files

5. Orientation file (*.ori)

```
!Image id              Camera                                  sig-XY
!-------------------------------------------------------------------------
GOPRO0001.jpg          GOPRO                                   0.000755
!time      omega       phi         kappa       X       Y       Z
!-------------------------------------------------------------------------
1.00       90.0        -30.0       0.0         -0.5    -1.5    0.5

GOPRO0002.jpg  GOPRO                                           0.000775
2.00           90.0        -30.0    90.0        -0. 5   -1.5    0.5
.
.
.
```

approximate values for EOPs

You need to come up with the EOPs for eight out of the sixteen images.

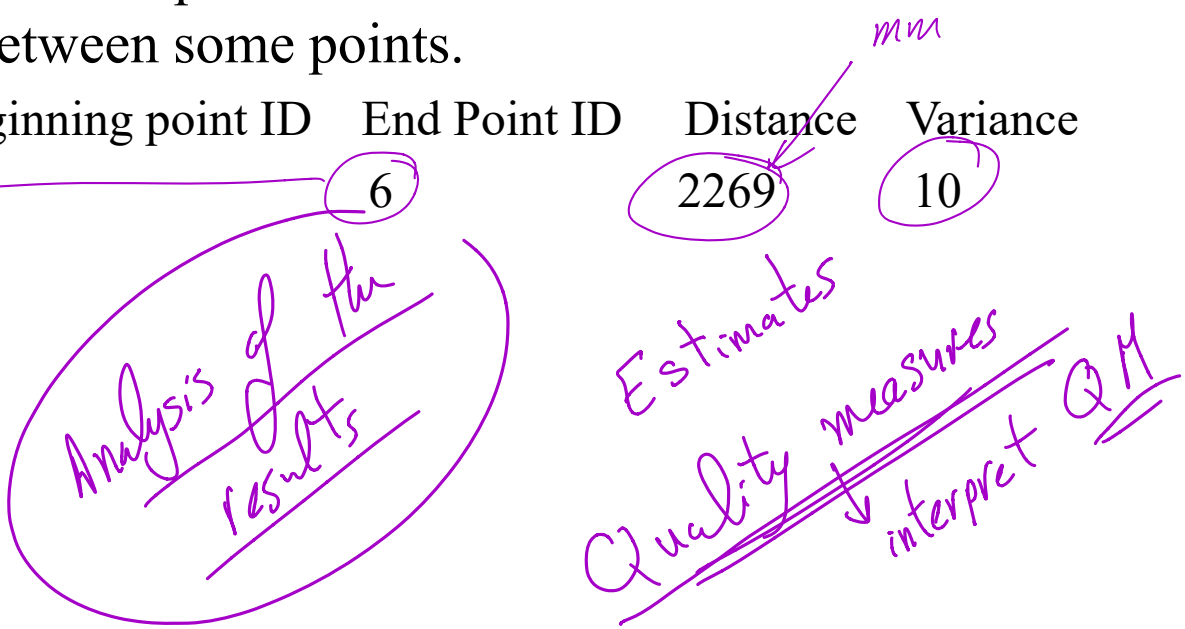
Step2: Sample Files

5. Distance file (*.dis)

- This file provides the distance measurements between some points.

!Beginning point ID End Point ID Distance Variance

2 6 2269 10



Deliverables and Report Preparation

- Measured image coordinates in mm as exported from **POOM**
- The rationale and procedure behind preparing the initial approximations of the unknown exterior orientation parameters
- The final camera characteristics including the distortion parameters (found in the *.out file)
- Tabulate your results for the EOPs of all images (found in the *.out file)
- The final residuals of the image coordinates (found in the *.res output file)
- The calculated variance component for each iteration (found in the *.sigma file)
- Explanation of any problems encountered

BASC Input *.ICF

input image coord. meas. & Confidence

datum definition through *.GCP

position & orientation of datum → *.dis

scale

approximate values for unknowns

X, Y, Z of object points (GCPs)

EOPs of image (ORI)

IOPs of Camera (*.Cam)

Complete ICF

ICF

Complete ORI

Image X_0, Y_0, Z_0 orientation ω, φ, κ

After Compilation

output — IOPs & (Variance-Covariance matrix)

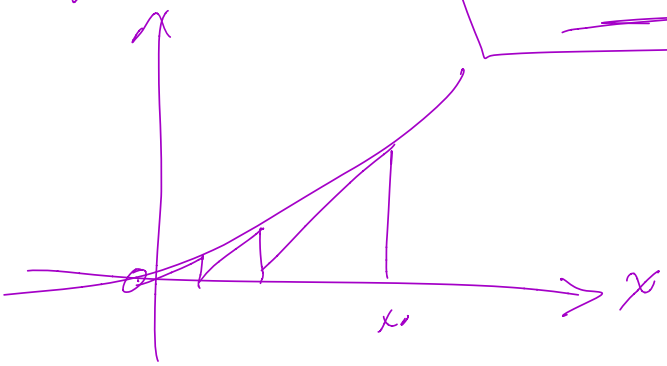
Confidence in the estimates

EOP & Variance-Covariance matrix

X, Y, Z of object points

Non-linear system : start from approximation

Iterative solution



$f(x) = \phi$

BASC

* *.prj Control iterations

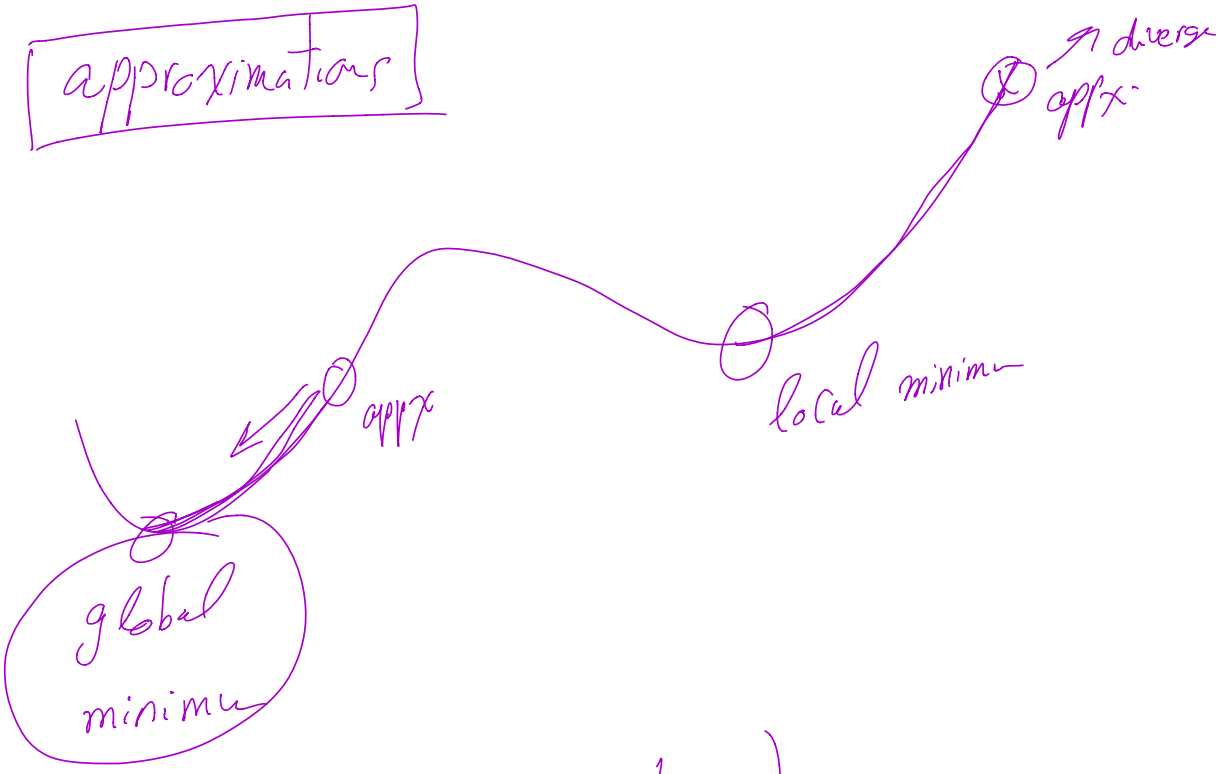
* max. # of iterations

* Convergence criterion

stable corrections/estimates are not changing

approximate values as initial guess parameters that you are fixing (e.g. t. depression data)

approximations



rough / far approximations

a) diverge

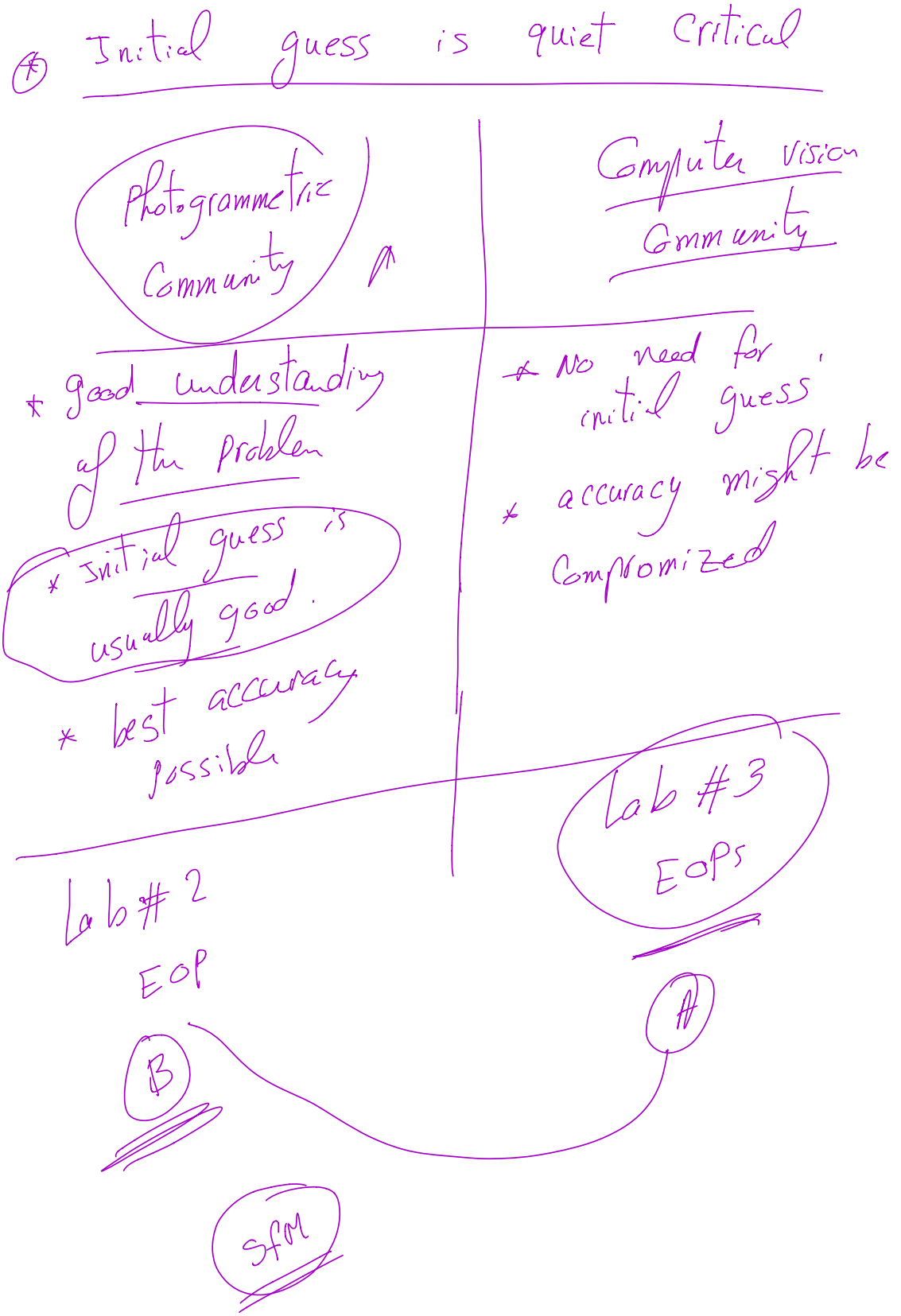
b) stuck in a local minimum

prior information

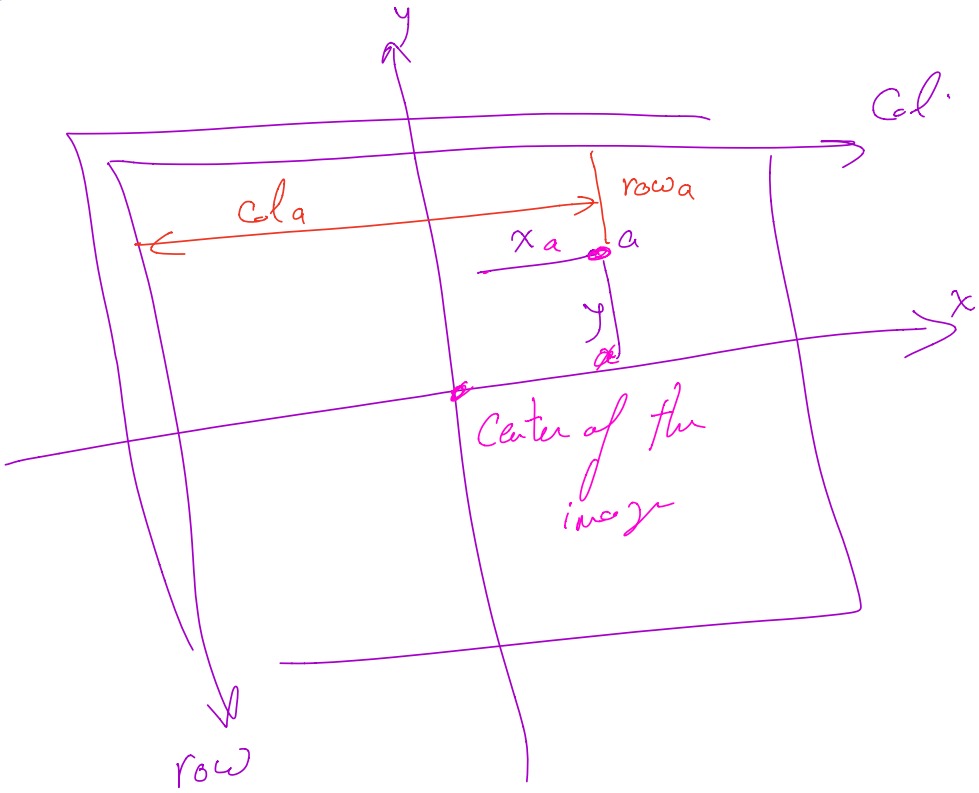
+ info that defines data

+ Known Camera characteristics

variance low variance

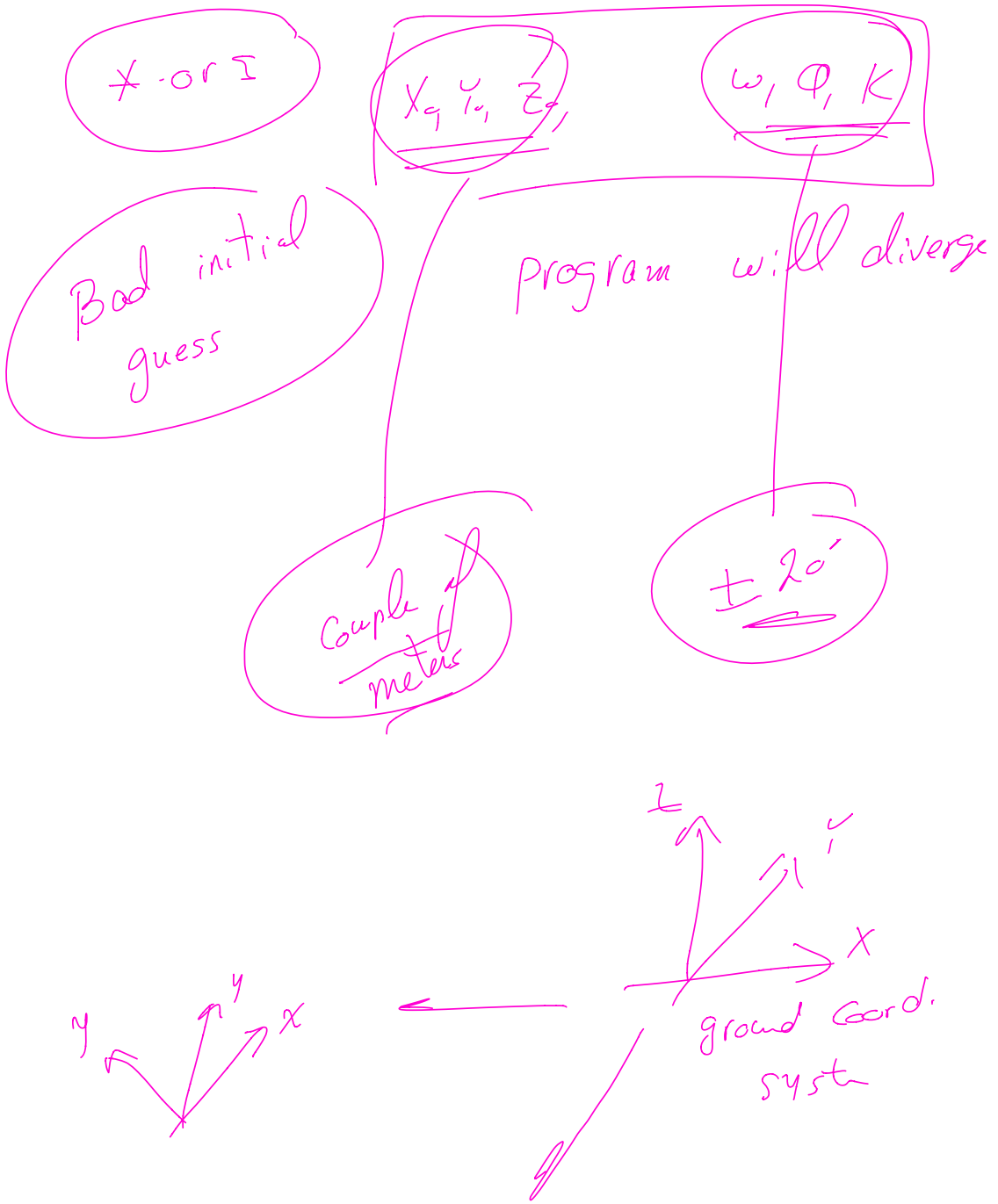

* Initial guess is quiet Critical
Photogrammetric Community
Computer vision Community
* good understanding of the problem
* Initial guess is usually good.
* best accuracy possible
* No need for initial guess
* accuracy might be Compromized
Lab #2 EOP
Lab #3 EOPs
B
A
SfM

* - SCF



$$\begin{pmatrix} x_a \\ y_a \end{pmatrix} = \begin{pmatrix} \left(col_a - \frac{\#\text{ of cols}}{2}\right) * \text{pix. size (mm)} \\ \left(\frac{\#\text{ of rows}}{2} - row_a\right) * \text{pix-size (mm)} \end{pmatrix}$$

in pixels


x - or I
X_q, Y_q, Z_q
ω, Φ, K
Bad initial guess
program will diverge.
Couple meters
$\pm 20'$
Z
Y
X
y
x
ground coord. syst