MAP PAGE UMR 694

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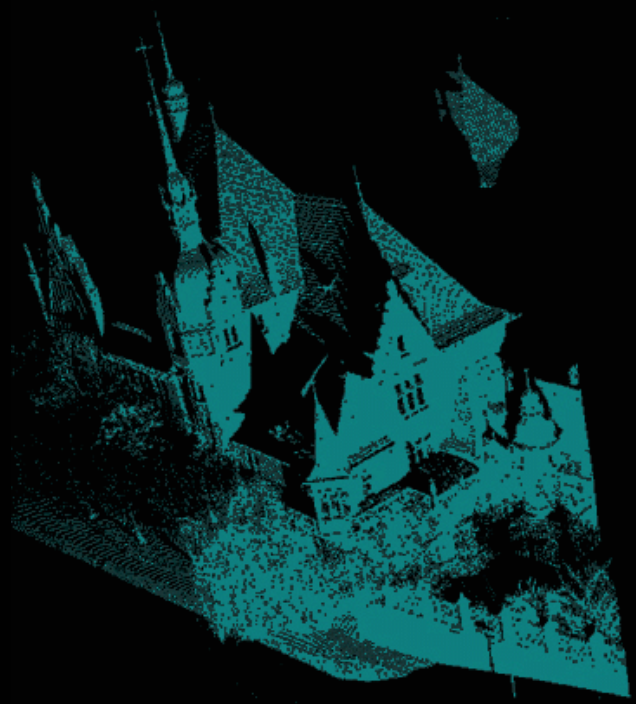
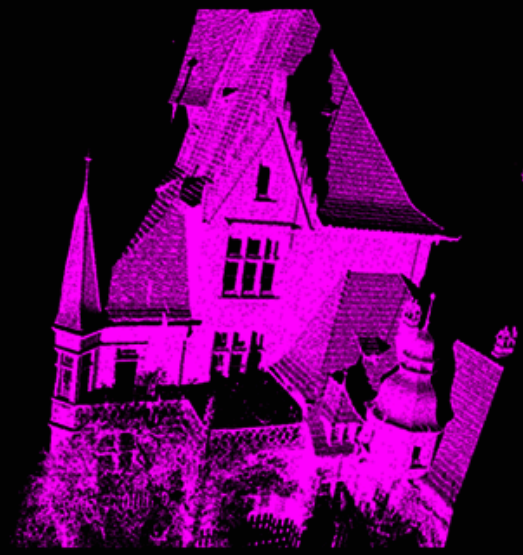
Slovenia

ICL: ITERATIVE CLOSEST LINE





A NOVEL POINT CLOUD REGISTRATION ALGORITHM BASED ON LINEAR FEATURES

Majd ALSHAWA

Presentation outline

- Objective
- State of the art
- Proposed method
- Test and experiment
- Conclusion and future work

What is 3D matching ?

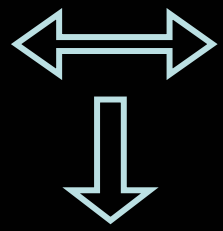
- Multiple scans for the same object
- Need to put them in the same coordinate frame

Objective

- match an unknown coordinate point cloud « data or scene » with a known coordinate cloud « model »
- Pairing + Rigid transformation

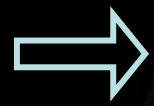
Particular case

Topographic scanner



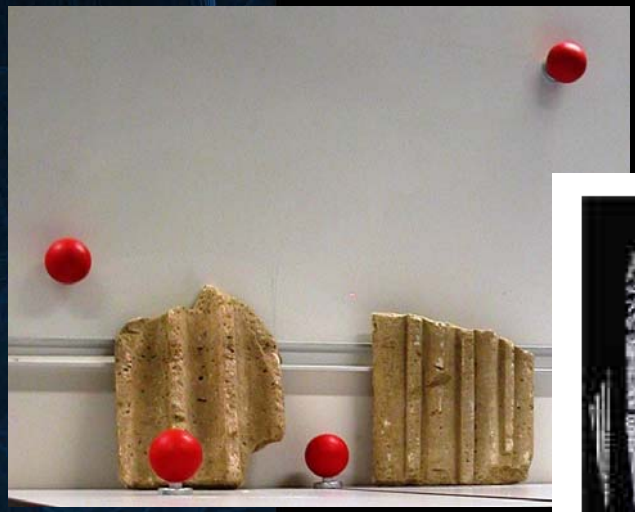
Real-time coordinate acquisition

Georeferenced point cloud



Superposition verification

State of the art

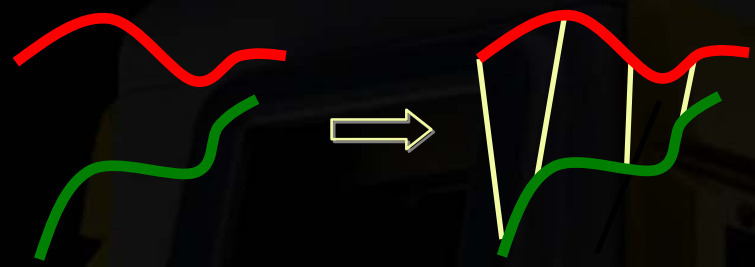


"château d'eau " details

- Spheres aiding registration
- Object-based registration

ICP Method : Iterative Closest Point

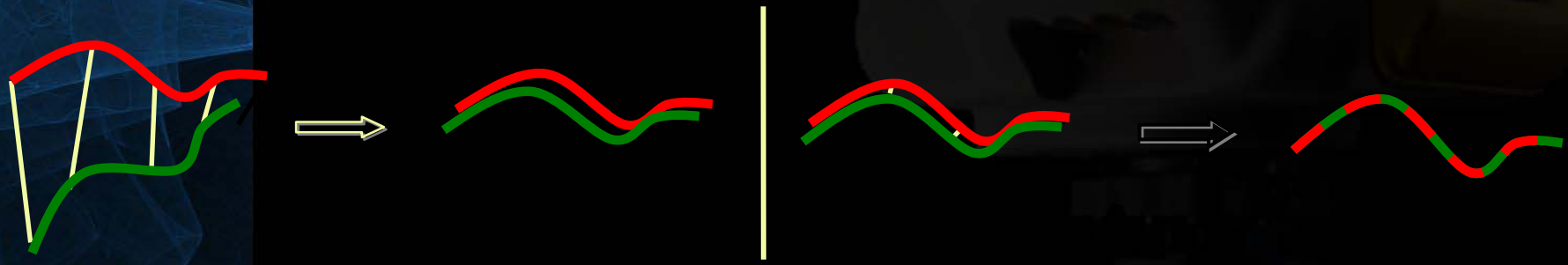
Iterate the following steps :



- Couple the nearest points
- Establish the error function :

$$E = \sum \left| Rp_i + t - q_i \right|^2$$

- Minimize this function and deduce rigid transformation components
- Apply this transformation to the data point cloud

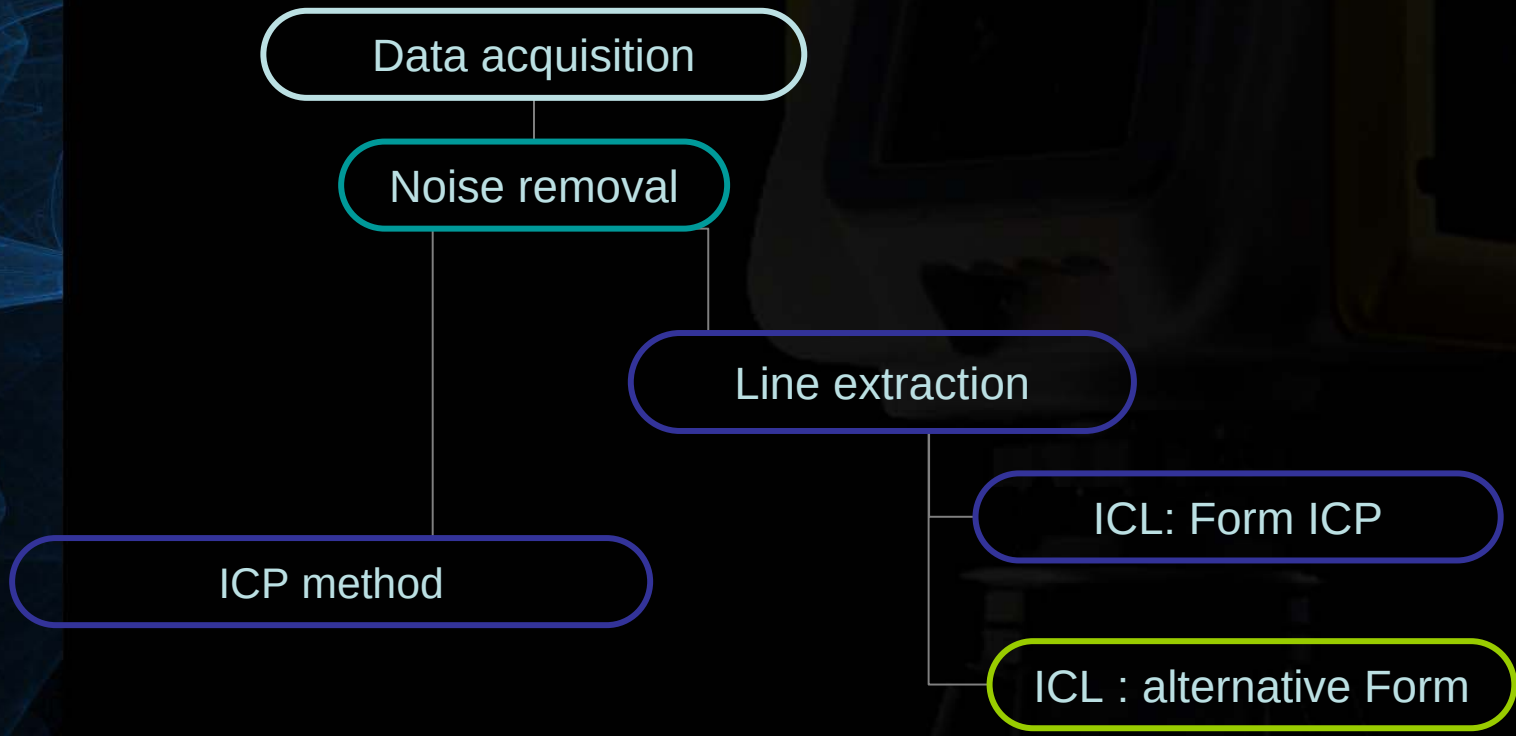


drawback:

High number of iterations to converge (unknown approximative coordinates)

Proposed method: ICL : Iterative Closest Line

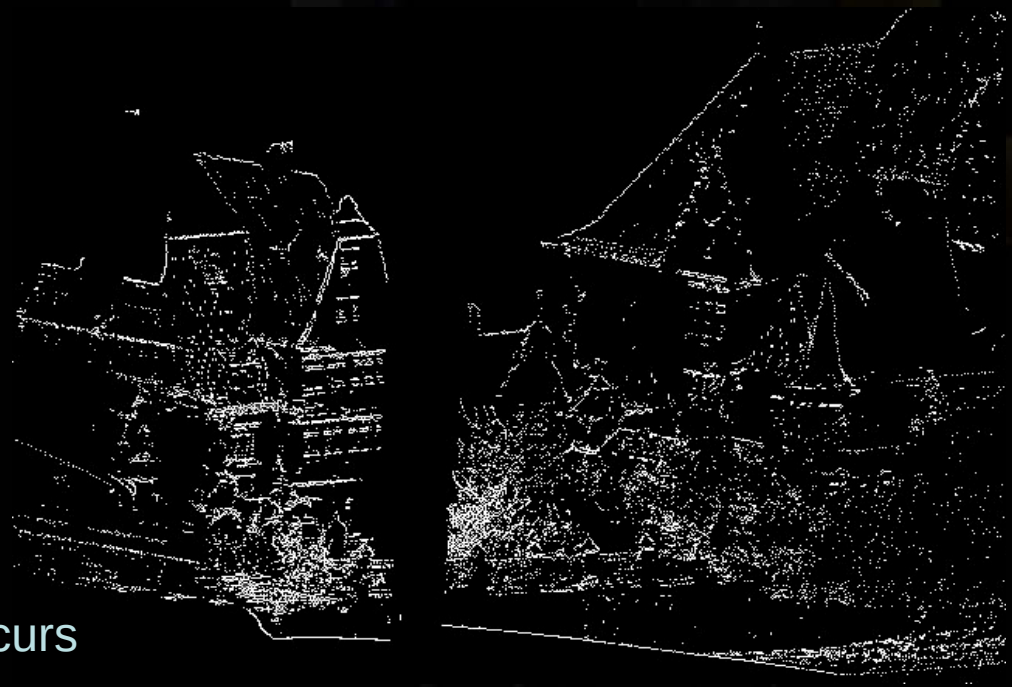
- ICL : an evolution of ICP
- Lines match geometric primitives



Why lines ?

- High detection possibility from many scans (invariant features)
- High registration control (two lines are sufficient)
- Reutilisation possible in other applications

Where?

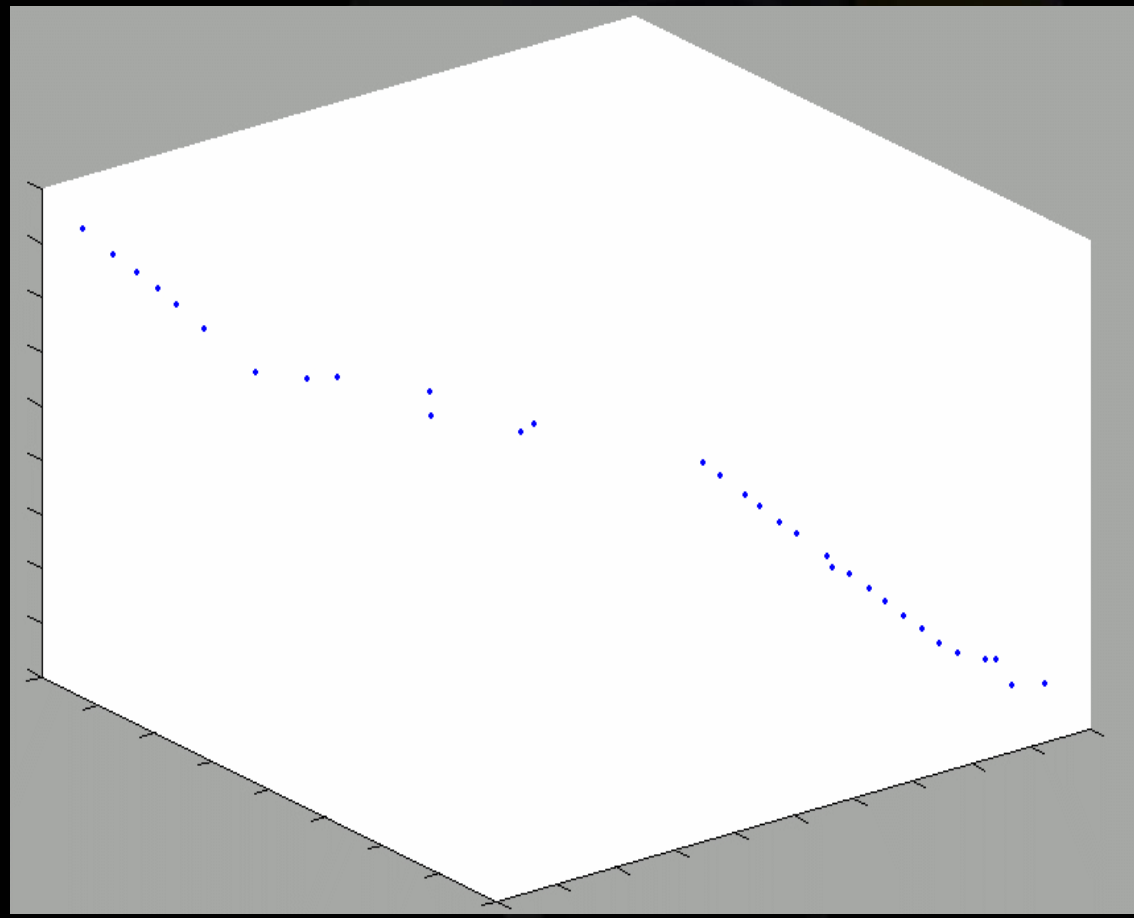


Points where a remarkable
normal direction change occurs

Line extraction

Incremental method

- Point by point modelisation
- Adding the closest point each time
- Least square adjustement to fit a line



Advantages:

- Simple and precise
- Low number of user-provided parameters

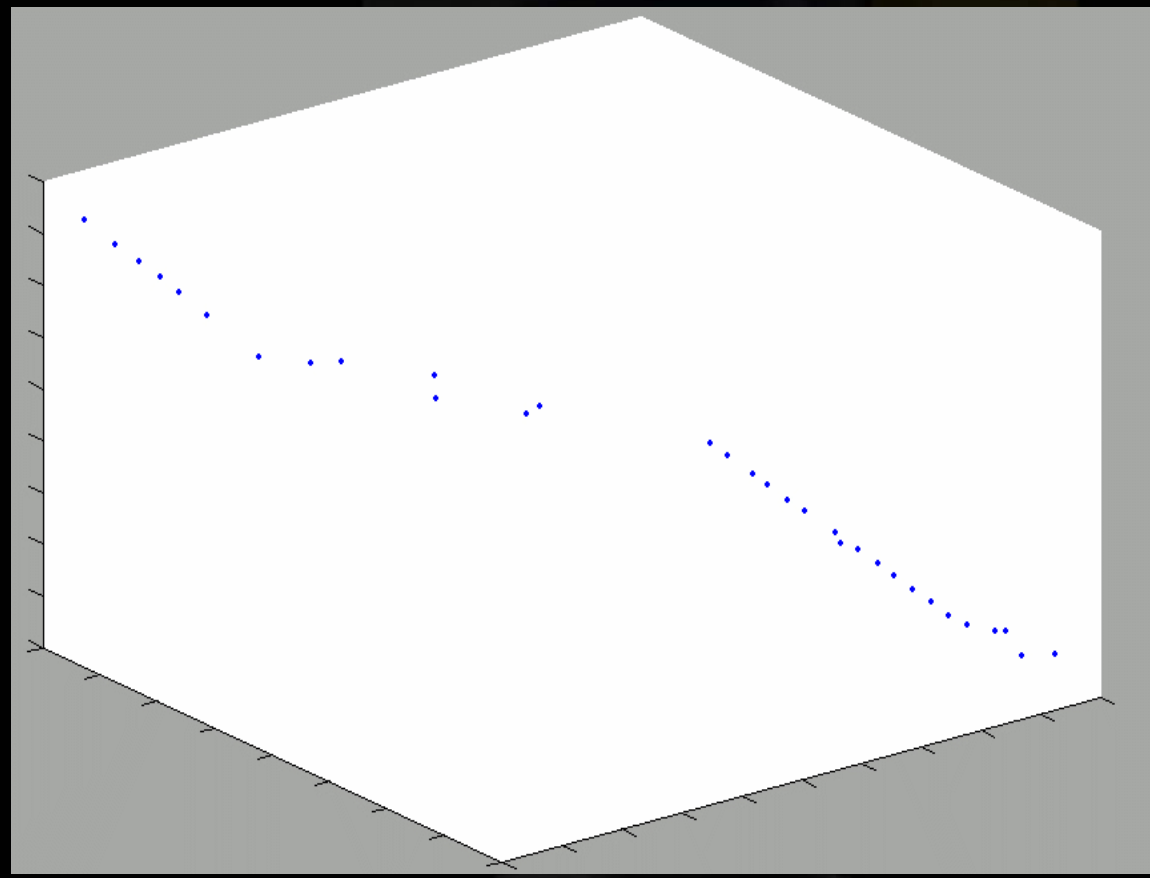
Drawback :

Execution time

Line extraction

RANSAC (Random Sample Consensus)

- Trace a line through two random points
- Measure all distances
- Point number – distance criteria
- Iterate the procedure until acceptable percentage of the cloud is modeled



Advantages:

- Simple fast method

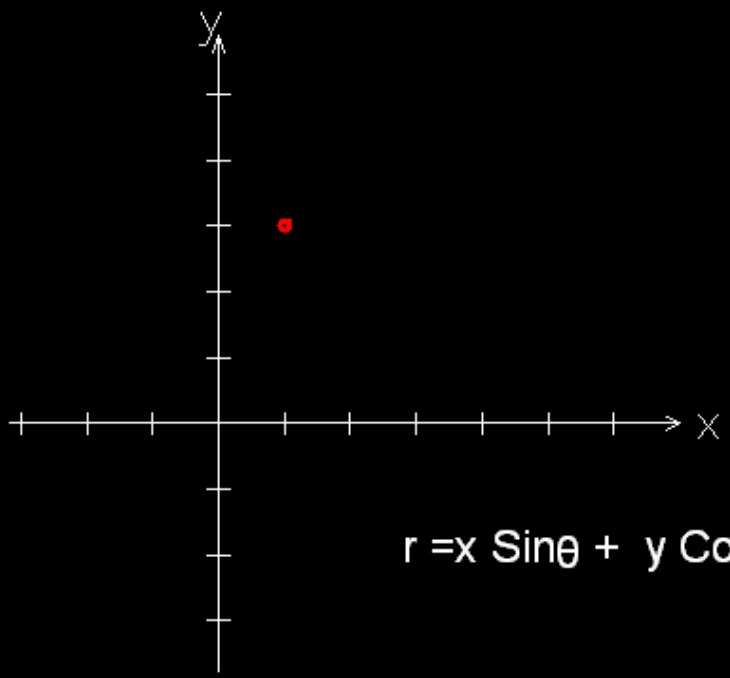
Drawback

- Probabilism

Line extraction

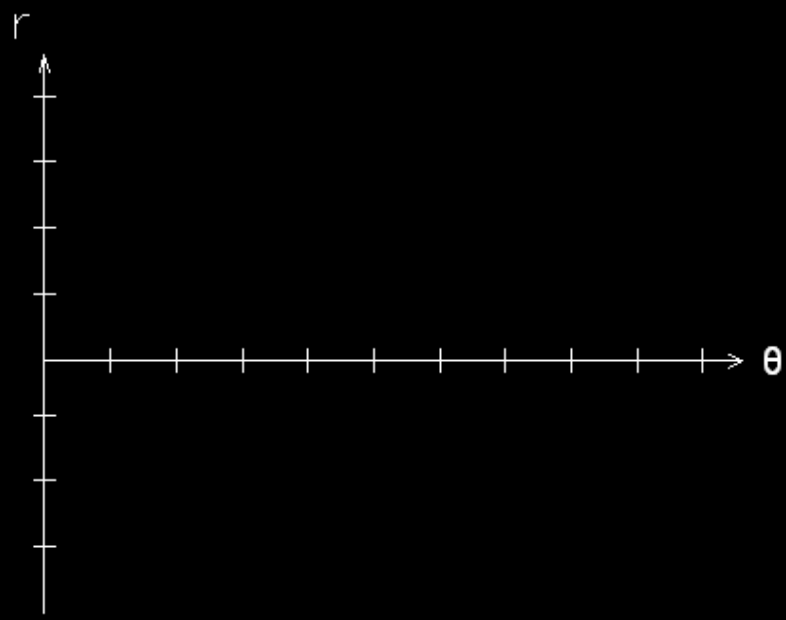
Hough Transform

Principle: line-point duality in 2D space (coordonnates-parameters)



$r = x \sin\theta + y \cos\theta$

COORDINATE SPACE

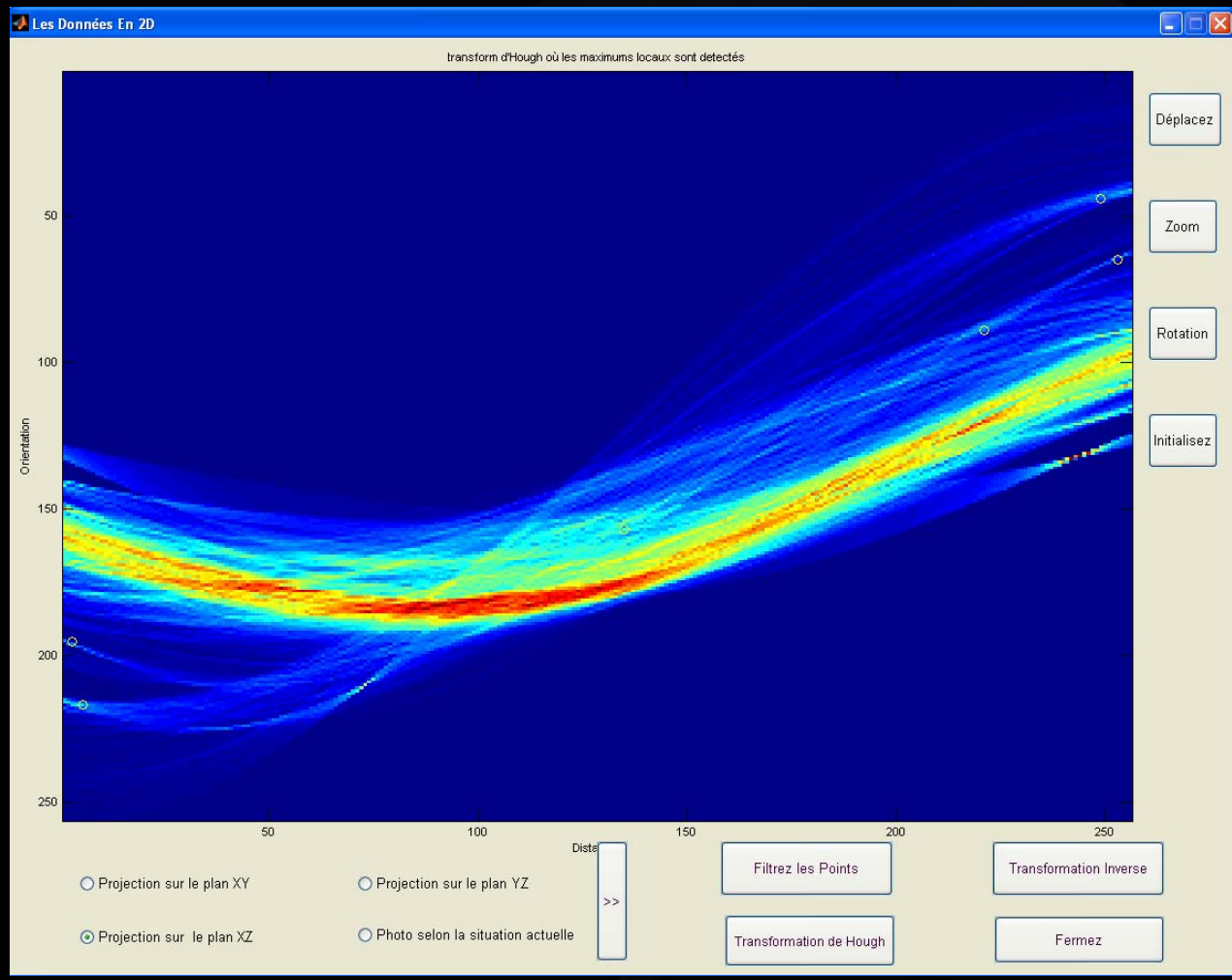


PARAMETER SPACE

Line extraction

Hough Transform

- Representing the curves on a histogram
- Regional maximums search
- Inversing the transform to detect the lines



Drawbacks:

- Too much threshold to provide
- Incapacity in some cases

advantage:

- Fast method

ICL Algorithm : ICP form

Iterate the following steps :

- Line pairing
- Error function establishement :

$$f(R,T) = \frac{1}{N_p}\sum_{i=1}^{N_p}\left\| o_{xi} - Ro_{pi} \right\|^2$$

- Rotation matrix (*R*) *calculation*
- Rotate the « data » cloud
- Shift (*T*) *calcuation*

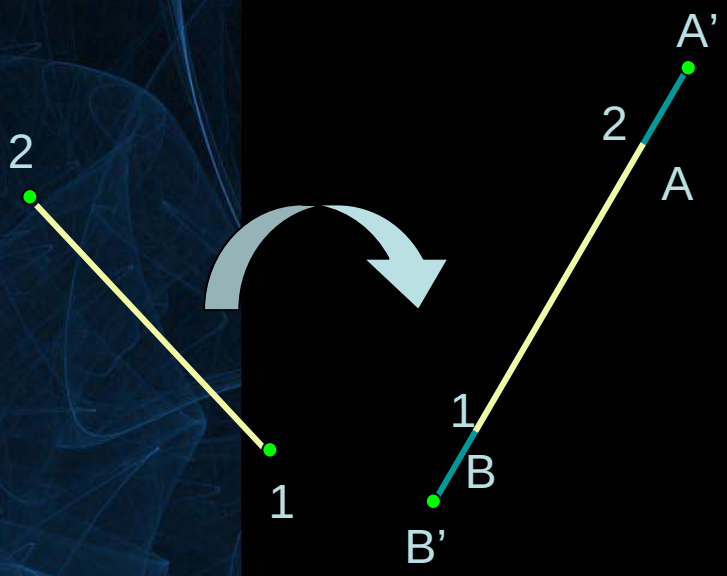
$$a_1' = R\,a_1 + T$$

$$a_2' = R\,a_2 + T$$

Non-inear problem

Linar problem

Alternative form



$$\begin{pmatrix} X_T \\ Y_T \\ Z_T \end{pmatrix} + R \begin{pmatrix} X_1 \\ Y_1 \\ Z_1 \end{pmatrix} = \begin{pmatrix} X_A \\ Y_A \\ Z_A \end{pmatrix} + \lambda_1 \begin{pmatrix} X_B - X_A \\ Y_B - Y_A \\ Z_B - Z_A \end{pmatrix}$$

$$\begin{pmatrix} X_T \\ Y_T \\ Z_T \end{pmatrix} + R \begin{pmatrix} X_2 \\ Y_2 \\ Z_3 \end{pmatrix} = \begin{pmatrix} X_A \\ Y_A \\ Z_A \end{pmatrix} + \lambda_2 \begin{pmatrix} X_B - X_A \\ Y_B - Y_A \\ Z_B - Z_A \end{pmatrix}$$

Habib et al 03

Unavoidable equation linearisation

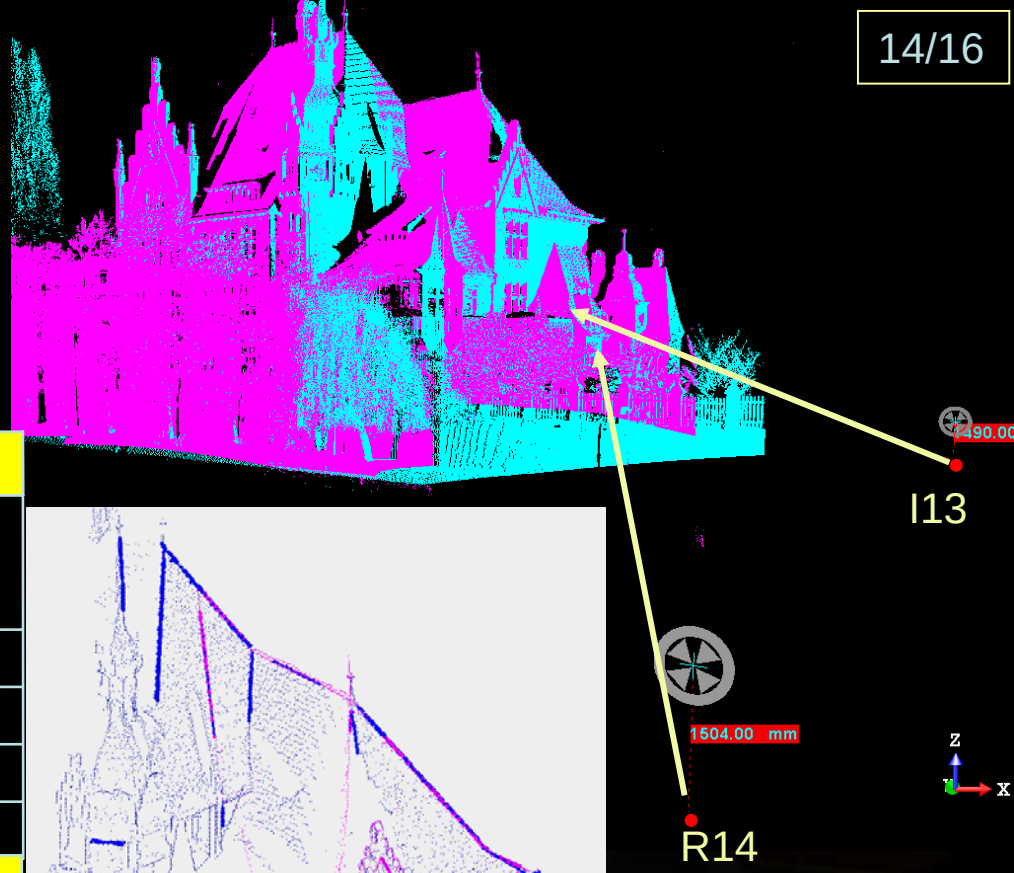
School of Pontonniers

Line extraction taking into account the following parameters:

ICL calculation:

ICL : ICP form			
rotation (m *gon*)	σ (m gon)	Shift (*cm*)	σ (*cm*)
linear resolution	30 mm at 60 m	0.2	50 mm at 60 m	0.2
Point number	601952	-0.8	292706	0.2
Potential point number	9527	0.3 RMS : 0.3 *cm*	15401	0.2

méthode ICL forme alternative			
Rotation(m Gon)	σ mGon	Shift (*cm*)	35 mm σ (*cm*)
Extracted lines	48	1.8	33	0.3
Paired lines	13	-1.5	0.3
		0.6	0.2
Coupling threshold	60 mm (distance), 0.5 degree (direction) RMS : 0.4 cm		



Two different scans

Conclusion

Line extraction

- Lack of an overall method encompassing all cases
- High sensitivity to thresholds
- Extracting lines in two steps: a more efficient solution

Registration

- High sensibility for the last step result
- The proposed method helps to evaluate the previous topographical operations

Positives / negatives

Advantages

- Highlighting the effect of the geometric complexity
- Accelerating the registration procedure

Drawbacks

- Hindrance when no protruding or recessed details exist
- Redundancy decrease according to line detection low accuracy

Perspectives

- Line extraction as plans contours
- Using other geometric features during the registration
- Potential point extraction study
- Supplying approximative coordinates


Thank you for your attention