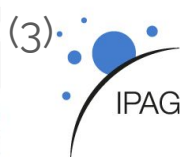


(Martian) DEM alignment using computer vision methods.

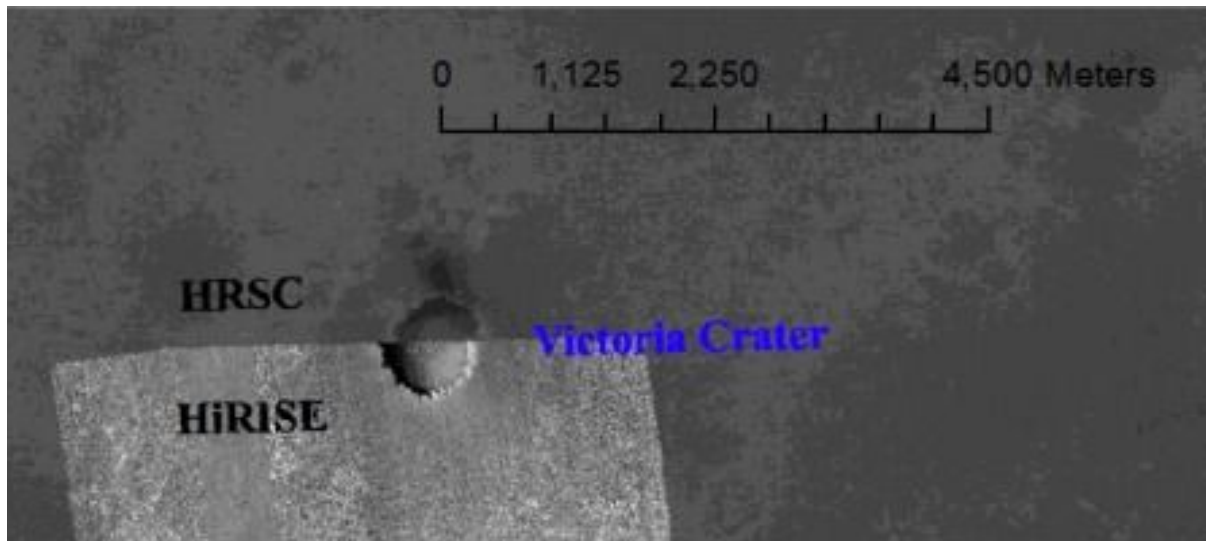
PhD Student : BRUN Loïs(1,2,3) (CV-)Director : PAIEMENT Adeline(1,2) (Planeto-)director : DOUTE Sylvain(3) Economic partner : BERNARD-SALAS Jeronimo(4)



Institut de Planétologie et
d'Astrophysique de Grenoble



1.Context : Misregistration



Victoria crater, HiRISE x HRSC (co-registered with MOLA),
misregistered mosaic @Tao et al. 2016

Misregistration :

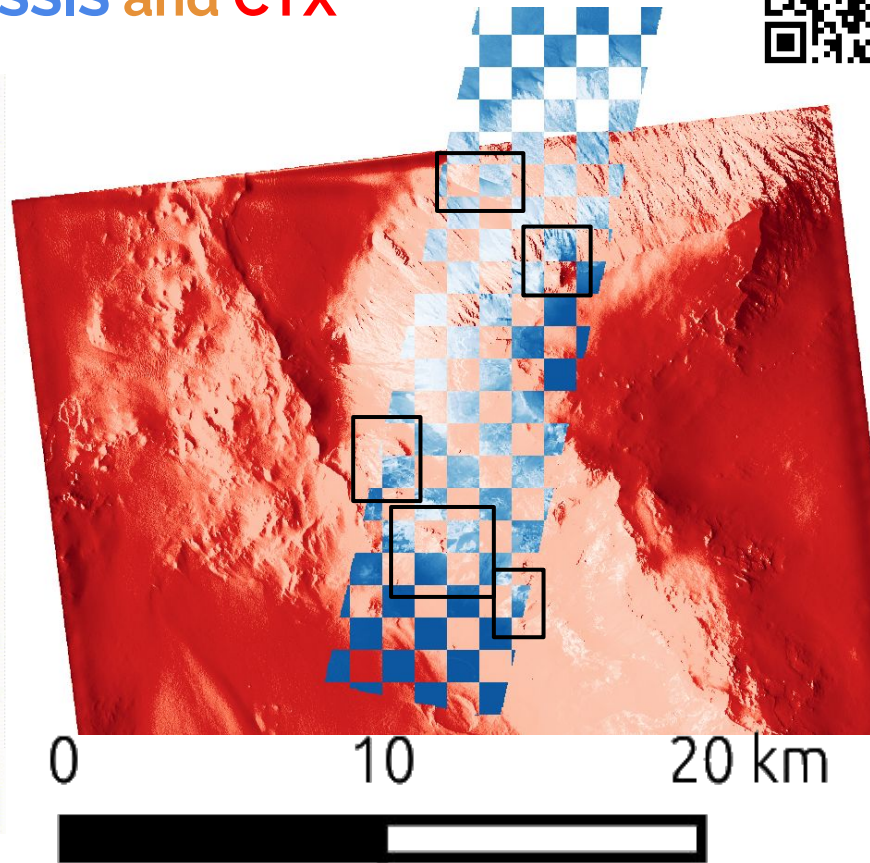
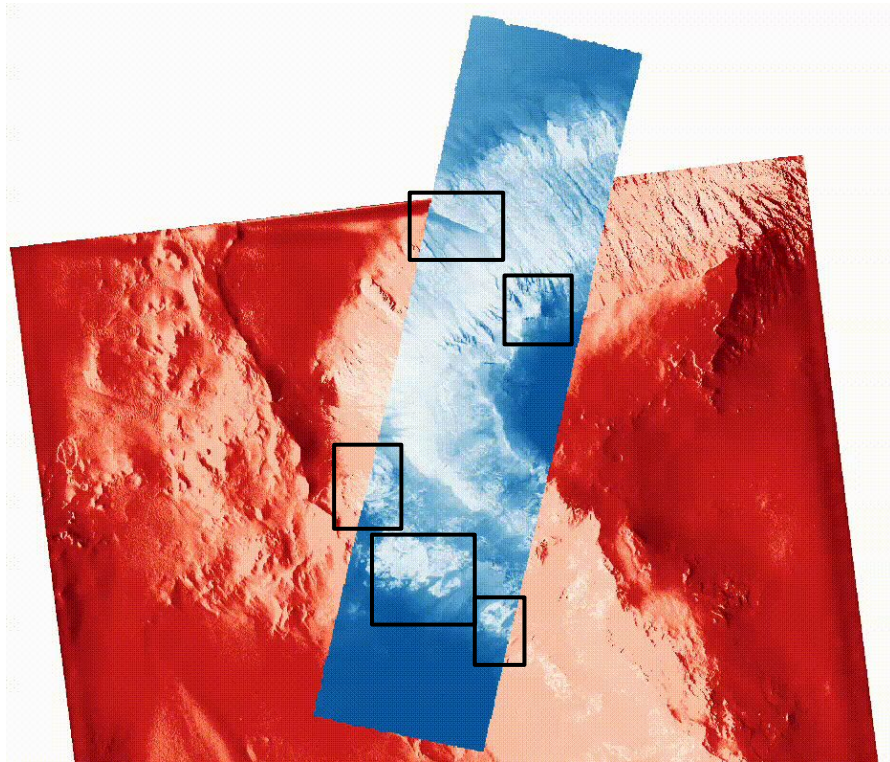
- Spatial **misalignment** between datasets of the same scene
- Common
- Tricky to deal with
- Prevent joint use before being dealt with



Need to find good ideas to fix this !

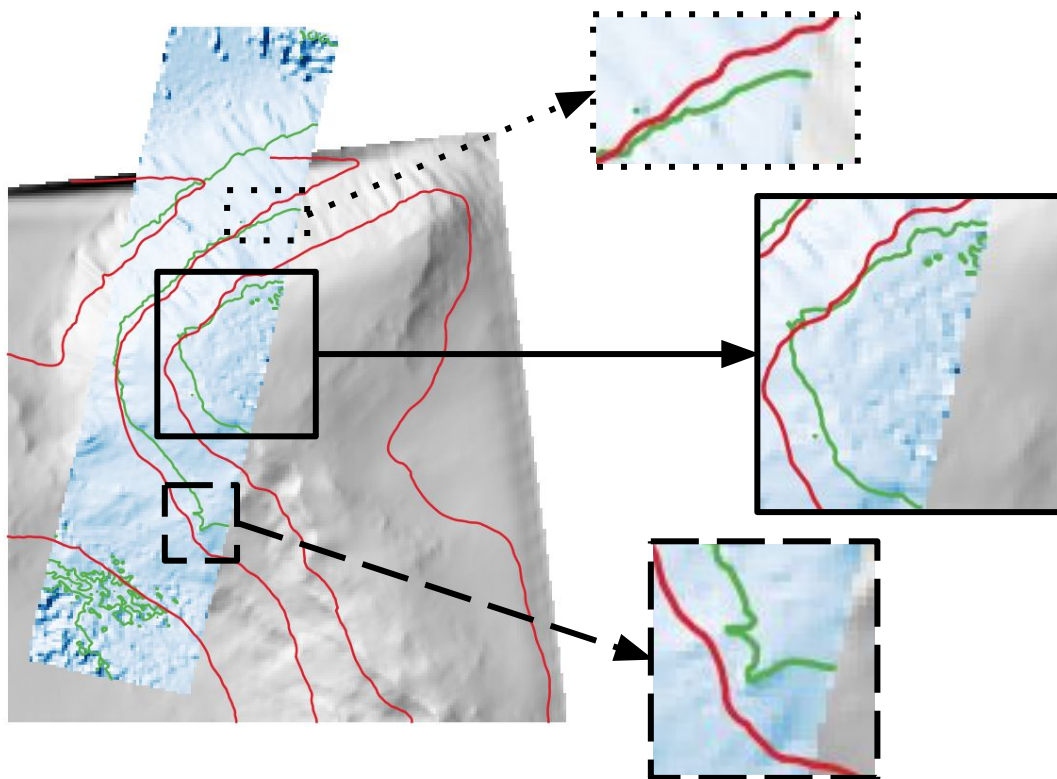
1.Context : Misregistration

Multi-sensor misregistration : CaSSIS and CTX



1.Context : Misregistration

Multi-captor misregistration : even on elevation levels !

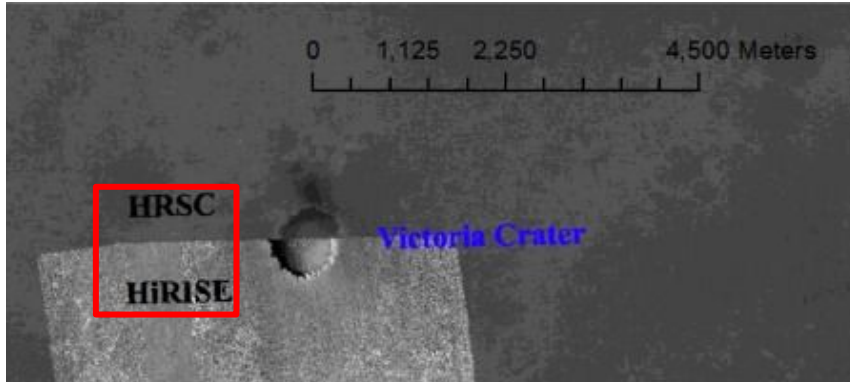


Legend :

- CaSSIS
 - DTM
 - Elevation Level
- CTX
 - DTM
 - Elevation Level
- Region of interest (ROI) 1
- ROI 2
- ROI 3

1.Context : What's the challenge ?

Easy, just use the crater ! 🙌

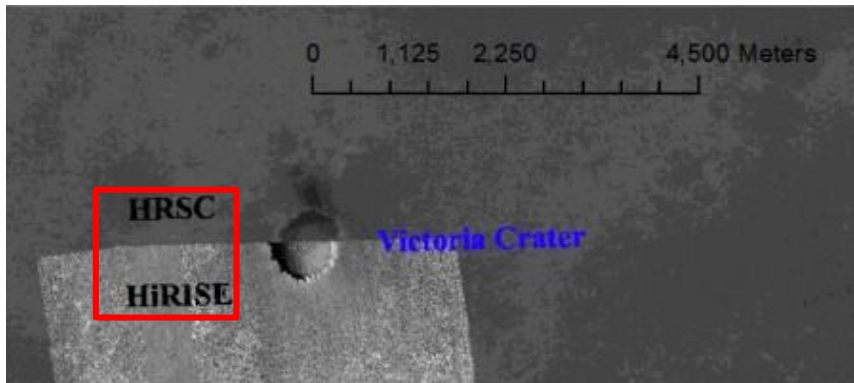


Not so easy 🙄



1.Context : What's the challenge ?

Easy, just use the crater ! 🙌

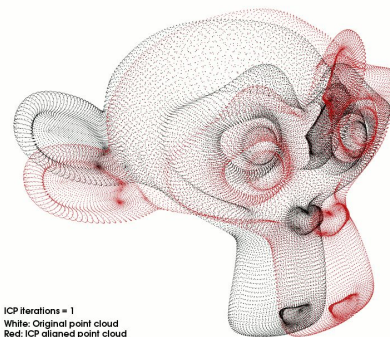


Not so easy 🙄



Standard registration algorithm →

- W/ features
- "Small" scale
- Same footprint
- W/ point2point correspondence

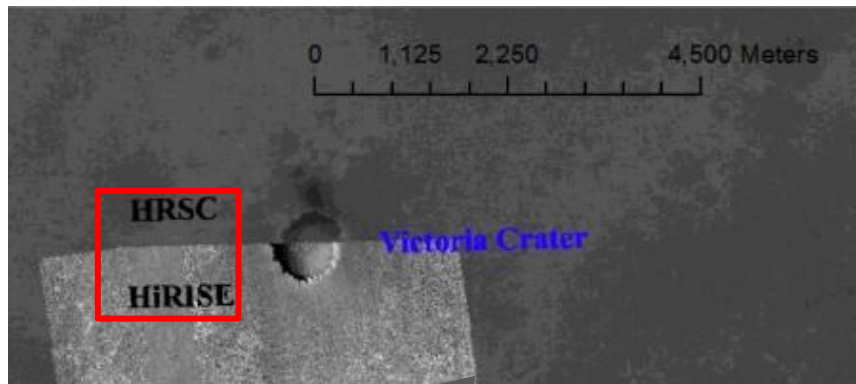


ICP Iterations = 1
White: Original point cloud
Red: ICP aligned point cloud

1.Context : What's the challenge ?

Easy, just use the crater ! 🤗

Not so easy 😞

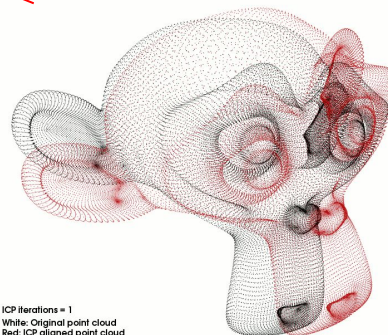


Need adaption

Underperform

Standard registration algorithm →

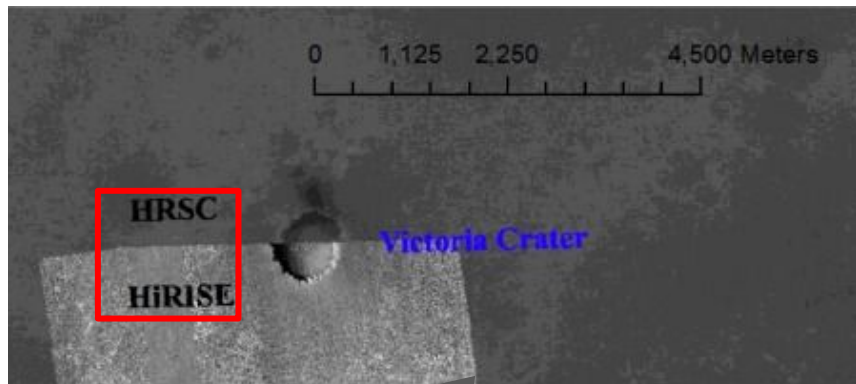
- W/ features
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Not so easy 😞

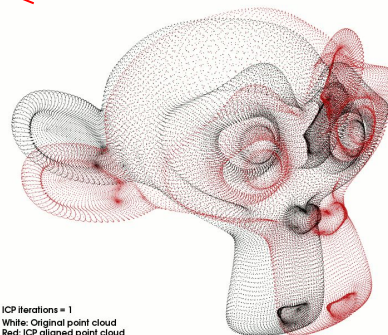


Need adaption

Underperform

Standard registration algorithm →

- W/ features
- "Small" scale
- Same footprint
- W/ point2point correspondence



Scientific goal :

Think outside standard procedures in order to bring a new registration algorithm designed for planetary data

2. Method : Key idea of IReSISD-DTM

Key idea : Precise registration requires geometric understanding

Geometric representation



Registration information

2. Method : Key idea of IReSISD-DTM

Key idea : Precise registration requires geometric understanding

Geometric representation



Registration information



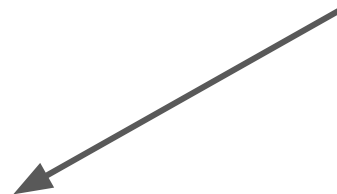
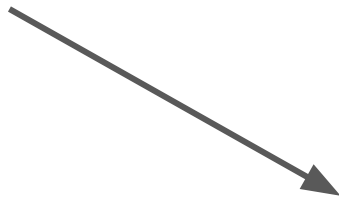
2. Method : Key idea of IReSISD-DTM

Key idea : Precise registration requires geometric understanding

Geometric representation



Registration information



Combined energy function : $E(\text{geo}, \text{reg})$

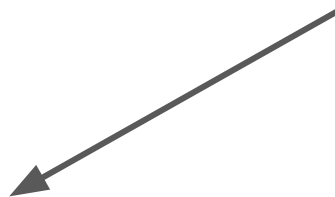
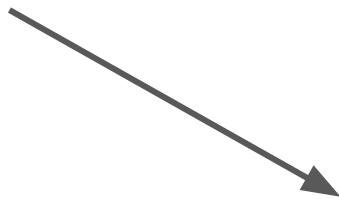
2. Method : Key idea of IReSISD-DTM

Key idea : Precise registration requires geometric understanding

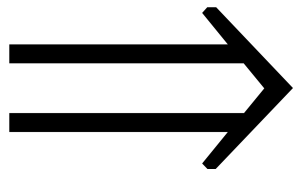
Geometric representation



Registration information



Combined energy function : $E(\text{geo}, \text{reg})$



Wide range of mathematical tools

Optimization
Geometry
Complex analysis

2. Method : Overview of IReSISD-DTM

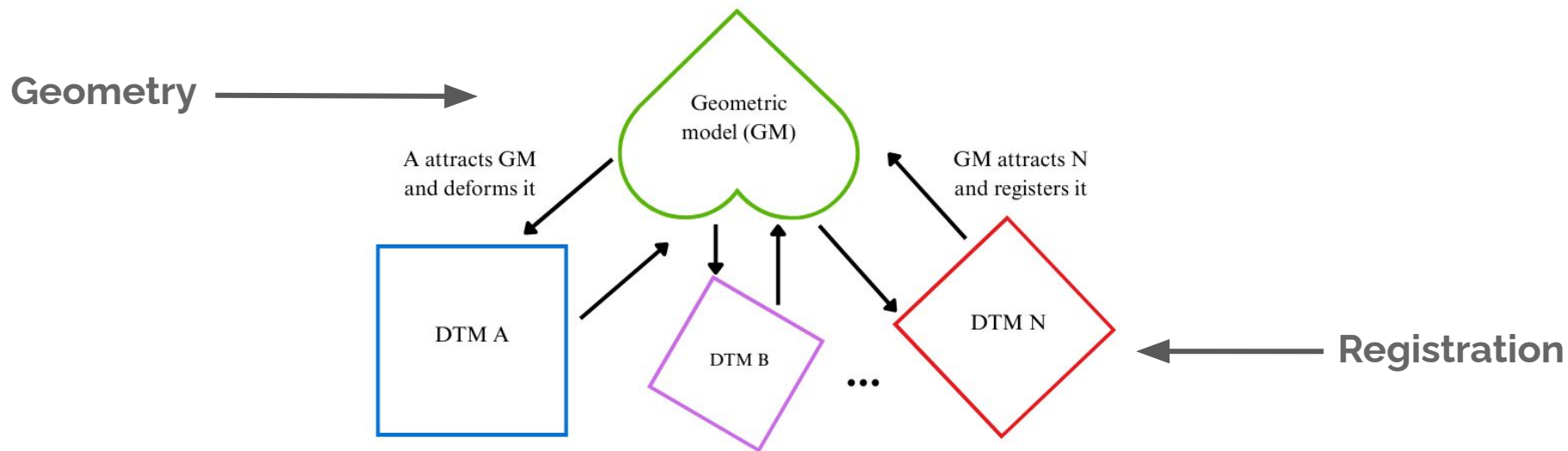
Iterative process of alternating optimisation between geometric representation of the set of data and registration

Key idea : We register DTMs to a common geometric model, not to each other !

2. Method : Overview of IReSISD-DTM

Iterative process of alternating optimisation between geometric representation of the set of data and registration

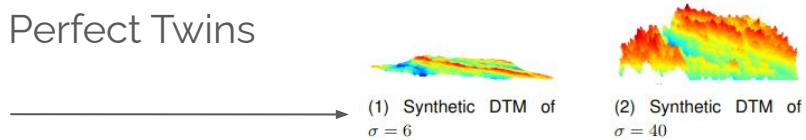
Key idea : We register DTMs to a common geometric model, not to each other !



3. Result : Validation strategy

Creating increasingly complex alignment challenges that closely resemble reality.

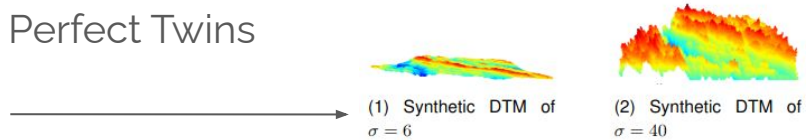
1. Perfect Twins



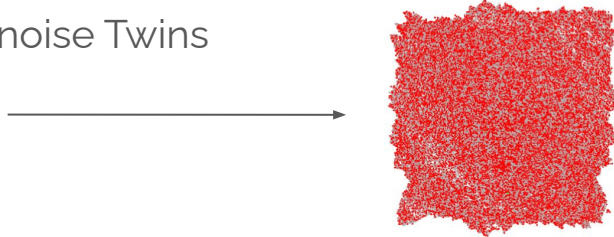
3. Result : Validation strategy

Creating increasingly complex alignment challenges that closely resemble reality.

1. Perfect Twins



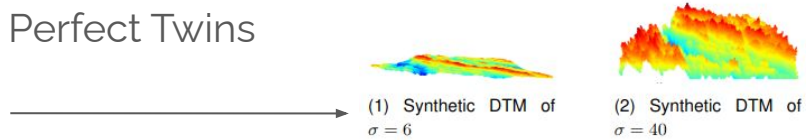
2. Gaussian noise Twins



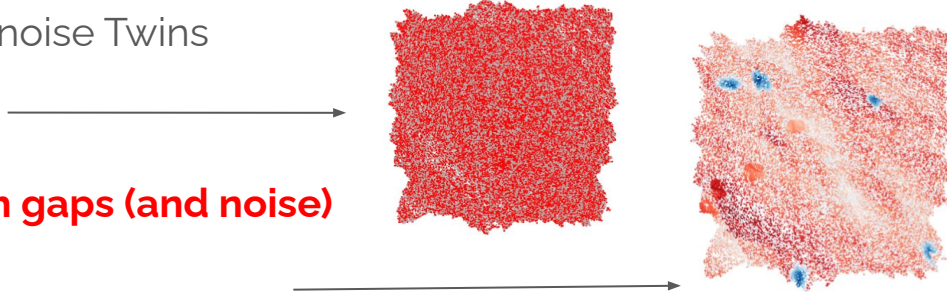
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Creating increasingly complex alignment challenges that closely resemble reality.

1. Perfect Twins



2. Gaussian noise Twins



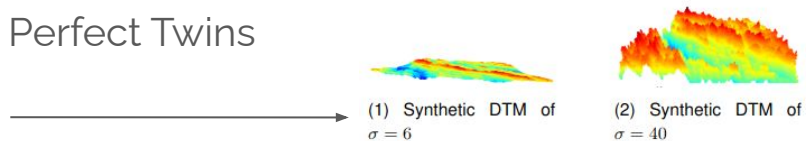
3. Twins with gaps (and noise)



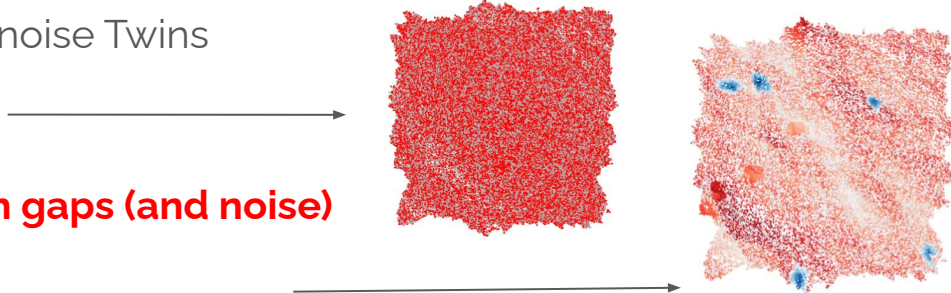
3. Result : Validation strategy

Creating increasingly complex alignment challenges that closely resemble reality.

1. Perfect Twins



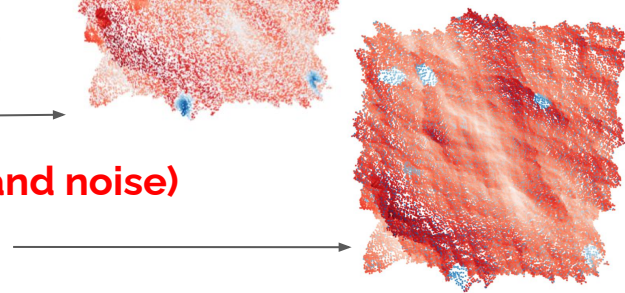
2. Gaussian noise Twins



3. Twins with gaps (and noise)



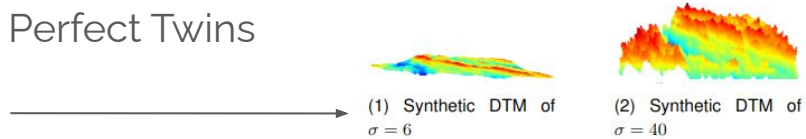
4. Twins with different resolution (and gaps and noise)



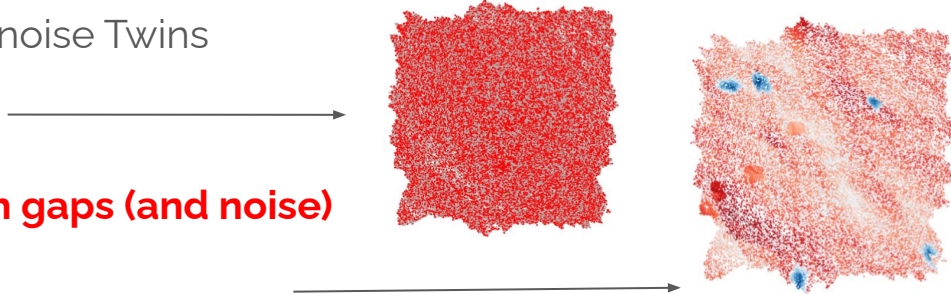
3. Result : Validation strategy

Creating increasingly complex alignment challenges that closely resemble reality.

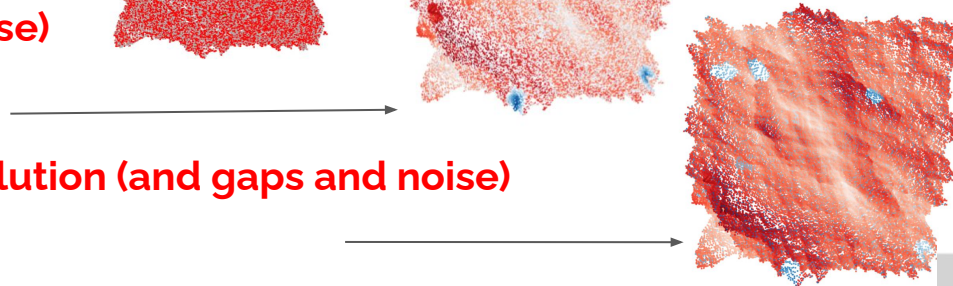
1. Perfect Twins



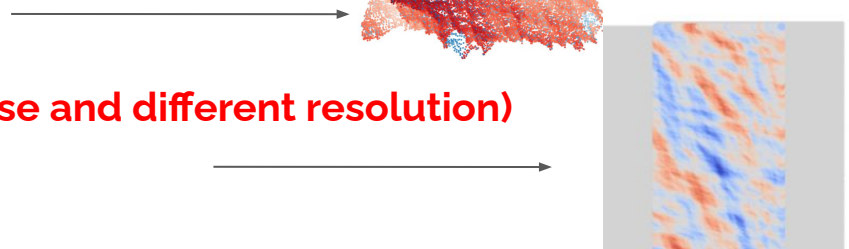
2. Gaussian noise Twins



3. Twins with gaps (and noise)



4. Twins with different resolution (and gaps and noise)



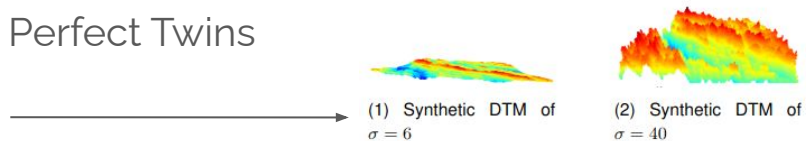
5. Twins partially overlapping (with gaps, noise and different resolution)



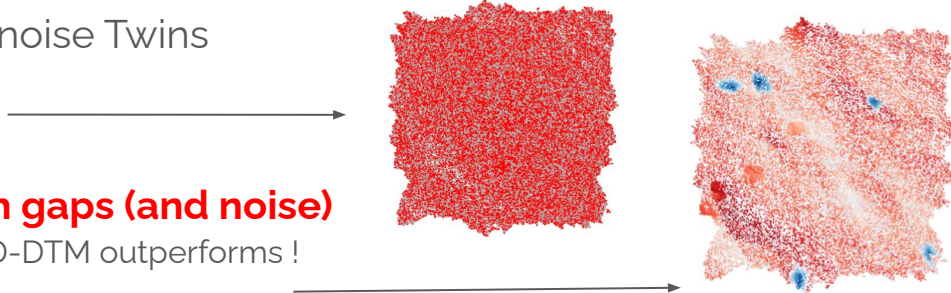
3. Result : Validation strategy

Creating increasingly complex alignment challenges that closely resemble reality.

1. Perfect Twins

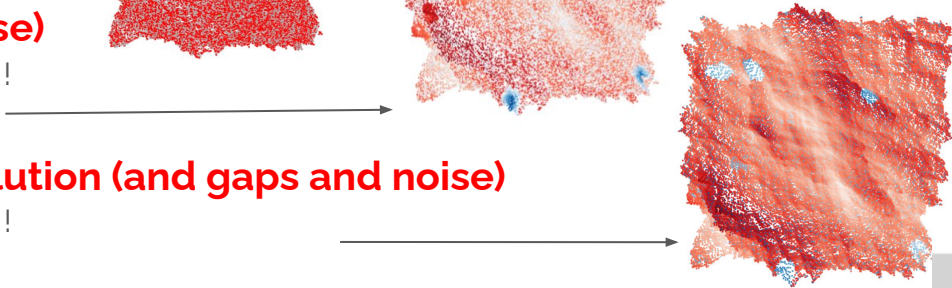


2. Gaussian noise Twins



3. Twins with gaps (and noise)

IReSISD-DTM outperforms !



4. Twins with different resolution (and gaps and noise)

IReSISD-DTM outperforms !

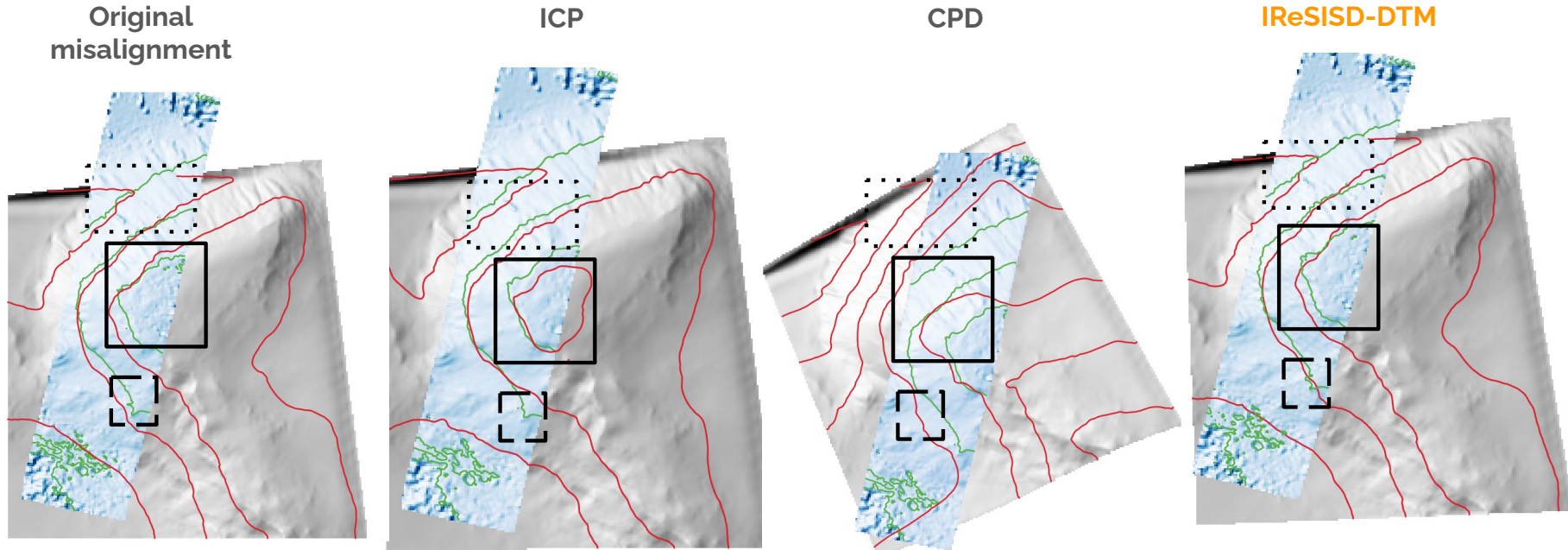


5. Twins partially overlapping (with gaps, noise and different resolution)

IReSISD-DTM outperforms !



3. Result : Hillshade visualization of the result



Handpicked
landmark voxel
distance :

8.7 vx

9.2 vx

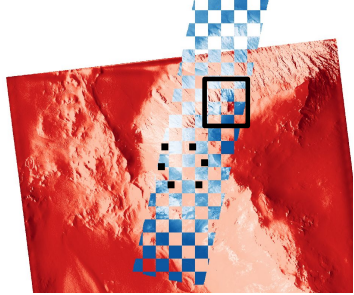
43.2 vx

7.0 vx

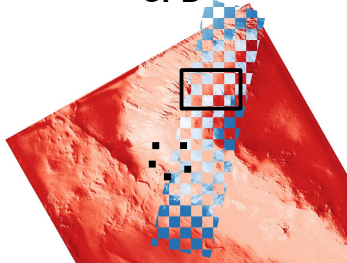
3. Result : Orthoimages visualization of the result



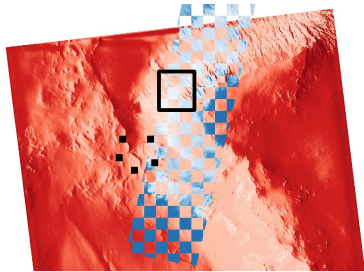
Original misalignment



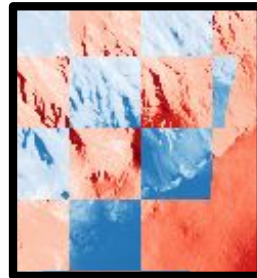
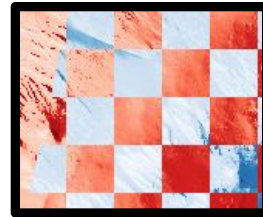
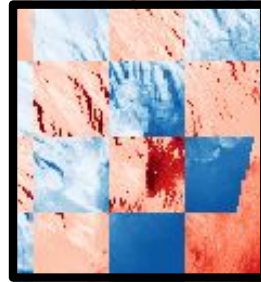
CPD



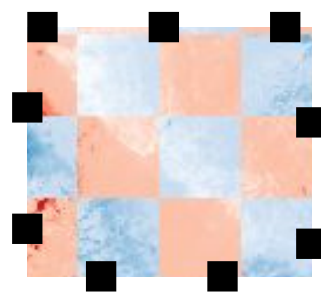
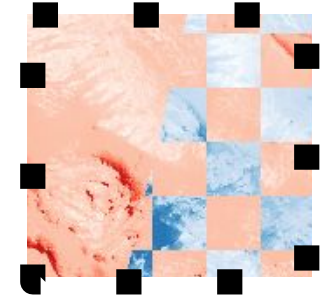
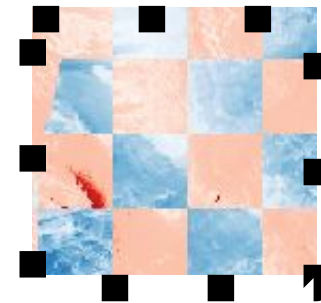
Proposed



ROI 1



ROI 2



DEM alignment using computer vision methods.

Recap :

1. **Misregistration** is really **commun** in remote sensing data
2. **Geometric understanding** is inherently linked with the **registration task**
3. **Additional context** is hidden in the **3D information**
4. We created **IReSISD-DTM**, a method **robust to challenging data**
5. We created a **dataset to benchmark** planetary data registration algorithm

Bibliography :

I am looking for work
opportunities starting 12/2026 !
email : lois.brun@lis-lab.fr



CV :



Our publications and presentations

1. Loïs Brun, Sylvain Douté, Jeronimo Bernard-Salas, Adeline Paiement. 3D registration of remote sensing data for planetary exploration. *CVPR 2026 - 3D Geometry Generation for Scientific Computing*, Jun 2026, Denver, United States. [hal-05620810](https://hal.archives-ouvertes.fr/hal-05620810)
2. Brun, L., Paiement, A., Doute, S., and Bernard Salas, J.: Alignment and fusion of digital terrain models : case study of planetary surfaces, EPSC-DPS Joint Meeting 2025, Helsinki, Finland, 7–12 Sep 2025, EPSC-DPS2025-1613, <https://doi.org/10.5194/epsc-dps2025-1613>, 2025.

Related literature

1. Paiement A, Mirmehdi M, Xie X, Hamilton MC. Integrated segmentation and interpolation of sparse data. *IEEE Transactions on Image Processing*. 2014; 23: 110-125.
2. A. Paiement, M. Mirmehdi, X. Xie, M. Hamilton: Registration and Modeling from Spaced and Misaligned Image Volumes. *IEEE Transactions on Image Processing (TIP)*, Vol. 25, Issue 9, pp. 4379-4393, 2016

Materials

- Code : https://gitlab.lis-lab.fr/lois.brun/iresisd-dtm_3d4science
- Dataset : <https://zenodo.org/records/20117117>