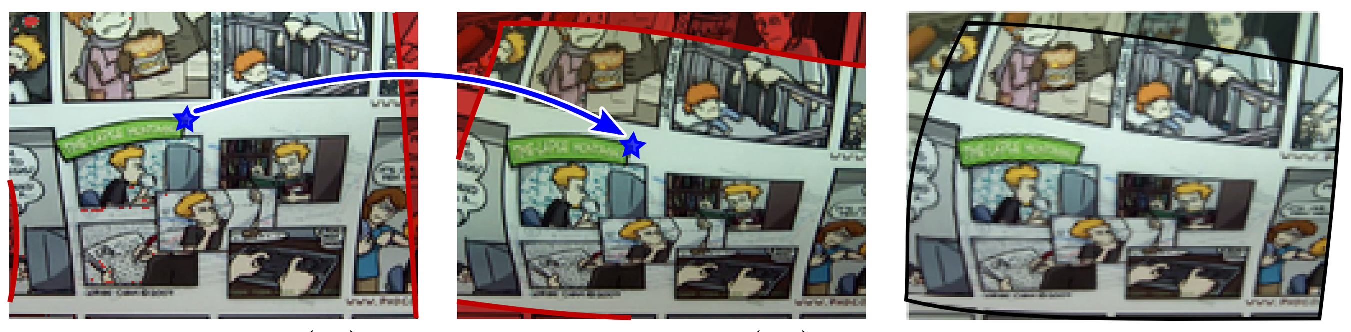
Direct Image Registration without Region of Interest

Goal and General Principle

Direct image registration: find the deformation that aligns the pixels of two images by using the colour information [2,3].



Source image ($\mathcal{S}$) Target image ($\mathcal{T}$) Mosaic *(warped source + target)*

Parametric formulation + least-squares:

$$\min_{\mathbf{p}} \sum_{\mathbf{q}\in\mathfrak{R}} \|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathcal{W}(\mathbf{q};\mathbf{p}))\|^2$$

Robust formulation using an M-estimator (for handling erroneous data caused by, for instance, occlusions):

$$\min_{\mathbf{p}} \sum_{\mathbf{q}\in\mathfrak{R}} \rho(\|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathcal{W}(\mathbf{q};\mathbf{p}))\|)$$

Problem: the Region of Interest (RoI)

Which pixels must be included in the region of interest?

Source image Target image Mosaic

- Rectangular region of interest defined manually
- Pixels of the RoI that do not belong to the overlap
- Pixels that could have been included in the RoI
- RoI determined automatically with our approach

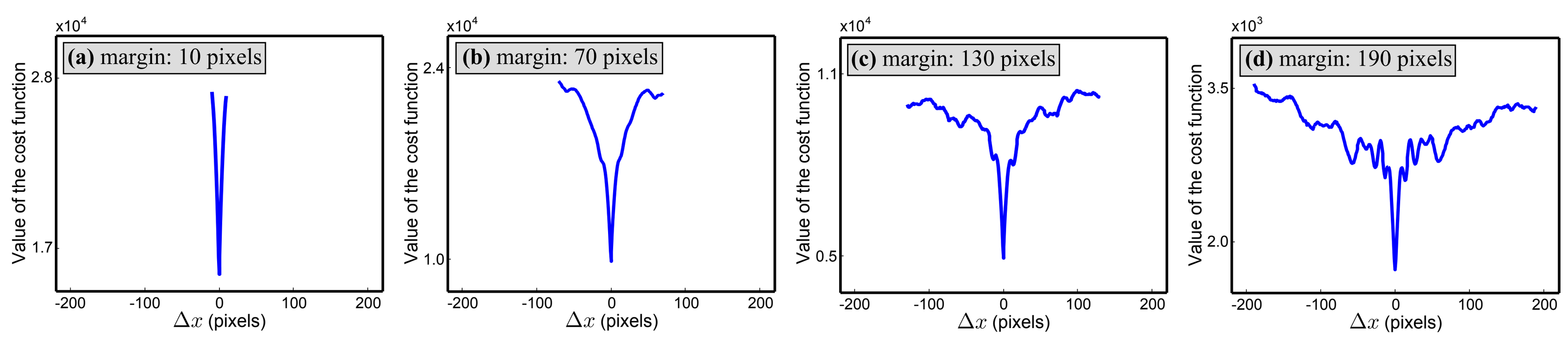
Region of Interest: State-of-the-Art

Rectangular Region of Interest

How can we determine the size of the rectangle?

- A large RoI may contain pixels that do not belong to the true overlap of the images.

- Using a small RoI leads in a loss of information that could have been useful. Besides, it results in a cost function hard to optimize.

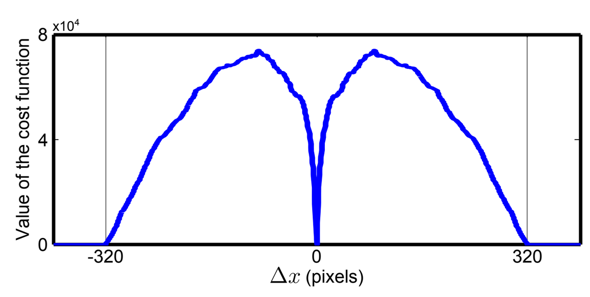


Adaptive Region of Interest [1]

Principle: consider all the pixels of the source image and, during each iteration of the optimization process, discard the ones that once warped fall outside of the target image.

$$\min_{\mathbf{p}} \sum_{\mathbf{q}\in\mathfrak{R}_A(\mathbf{p})} \|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathcal{W}(\mathbf{q};\mathbf{p}))\|^2$$

Drawbacks:
- Ill-posed problem (infinite number of minima)
- Dependance in $\mathbf{p}$ of $\mathfrak{R}_A$: hard to optimize
- Non-robust approach



Some References

[1] B. Pires et P. Aguiar. Registration of images with small overlap. *Proceedings of the IEEE sixth workshop on multimedia signal processing*, 2004.
[2] A. Bartoli. Groupwise geometric and photometric direct image registration. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 2008.
[3] M. Irani et P. Anandan. About direct methods. *Workshop on Vision Algorithms*, 1999.

Compatible Pixels

The **standard approach** may be seen as the relaxation of another problem that estimates the geometric deformation by **maximizing the number of compatible pixels**.

$\mathfrak{C}(\mathbf{p})$: set of compatible pixels

$$\mathfrak{C}(\mathbf{p}) = \{\mathbf{q}\in\Omega_{\mathcal{S}} \mid \mathcal{S}(\mathbf{q}) = \mathcal{T}(\mathbf{q}')\}$$

$$\chi_{\mathfrak{C}(\mathbf{p})}(\mathbf{q}) = \begin{cases} 1 & \text{if } \mathbf{q}\in\mathfrak{C}(\mathbf{p}) \\ 0 & \text{otherwise}\end{cases}$$

$$\text{find } \mathbf{p} \text{ such that } \prod_{\mathbf{q}\in\Omega_{\mathcal{S}}} \chi_{\mathfrak{C}(\mathbf{p})}(\mathbf{q}) = 1$$

The definition domain of $\mathcal{T}$ is not infinite: introducing a RoI $\mathfrak{R}$

Taking noise into account (normally-distributed)

$$\mathfrak{C}^R(\mathbf{p}) = \{\mathbf{q}\in\Omega_{\mathcal{S}} \mid (\mathbf{q}\in\mathfrak{R}) \wedge (\mathcal{S}(\mathbf{q}) = \mathcal{T}(\mathbf{q}'))\}$$

$$\mu_{\mathfrak{C}^R(\mathbf{p})}(\mathbf{q}) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{\|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathbf{q}')\|^2}{2\sigma^2}\right)$$

$$\max_{\mathbf{p}} \prod_{\mathbf{q}\in\mathfrak{R}} \mu_{\mathfrak{C}^R(\mathbf{p})}(\mathbf{q})$$

$$\min_{\mathbf{p}} \sum_{\mathbf{q}\in\mathfrak{R}} \|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathcal{W}(\mathbf{q};\mathbf{p}))\|^2$$

Our Approach

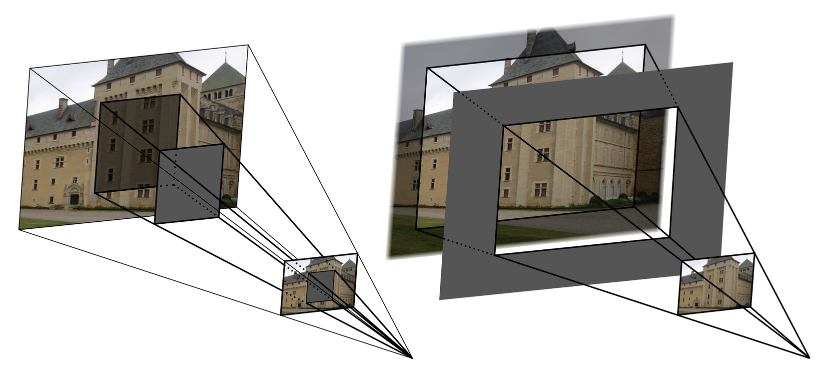
Our approach is a different relaxation that allows one **to drop the need of a region of interest**.

The pixels $\mathbf{q}$ and $\mathbf{q}'$ are compatible if the values $\mathcal{S}(\mathbf{q})$ and $\mathcal{T}(\mathbf{q}')$ are similar when $\mathbf{q}'\in\Omega_{\mathcal{T}}$ and not compatible otherwise.

$$\mathfrak{C}^T(\mathbf{p}) = \{\mathbf{q}\in\Omega_{\mathcal{S}} \mid (\mathbf{q}'\in\Omega_{\mathcal{T}}) \wedge (\mathcal{S}(\mathbf{q}) = \mathcal{T}(\mathbf{q}'))\}$$

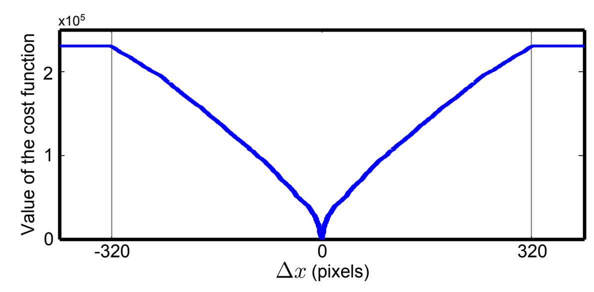
$$\mu^N_{\mathfrak{C}^T(\mathbf{p})}(\mathbf{q}) = \begin{cases} \exp(-\rho(\|\mathcal{S}(\mathbf{q}) - \mathcal{T}(\mathbf{q}')\|)) & \text{if } \mathbf{q}'\in\Omega_{\mathcal{T}} \\ \exp(-\rho(\alpha)) & \text{otherwise}\end{cases}$$

A pixel $\mathbf{q}$ such that $\mathbf{q}'\notin\Omega_{\mathcal{T}}$ has the same influence on the cost function as a pixel that corresponds to an outlier.

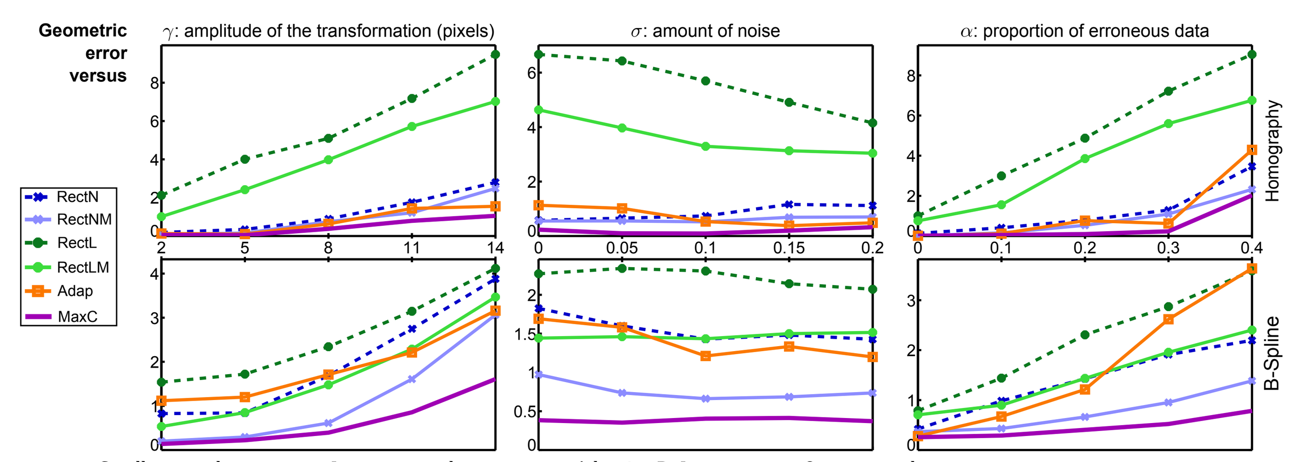


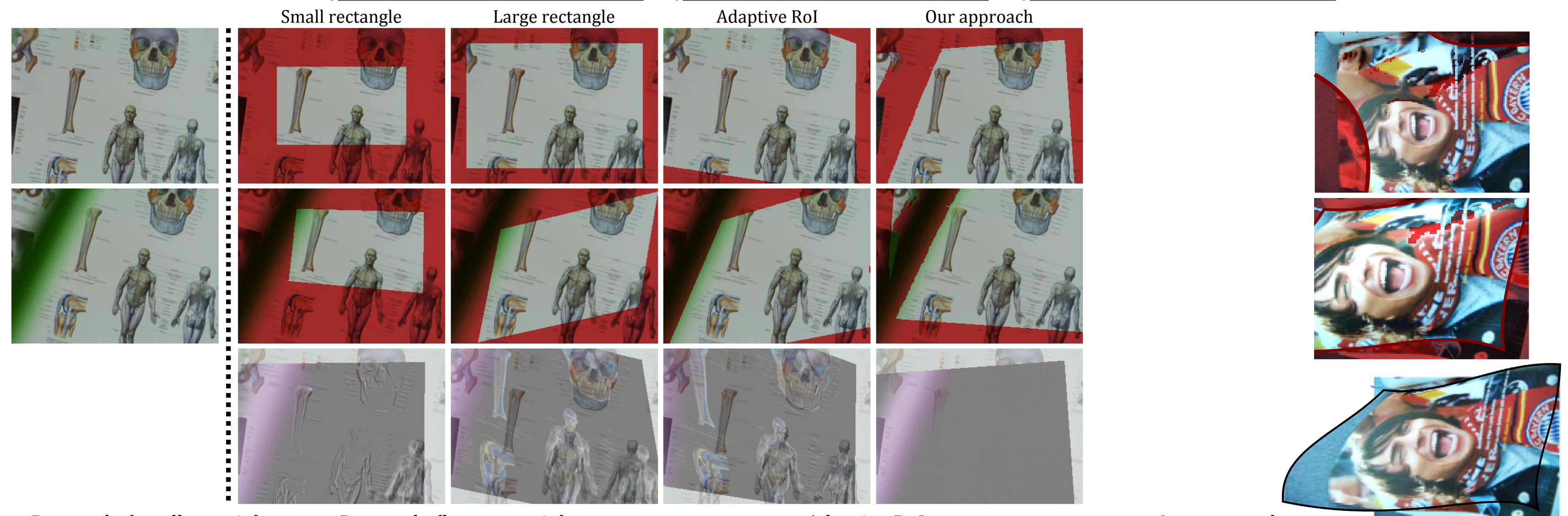
$$\boxed{\min_{\mathbf{p}} \sum_{\mathbf{q}\in\Omega_{\mathcal{S}}} \rho(\|\mathcal{S}(\mathbf{q}) - \mathcal{T}_\infty(\mathbf{q}')\|)}$$

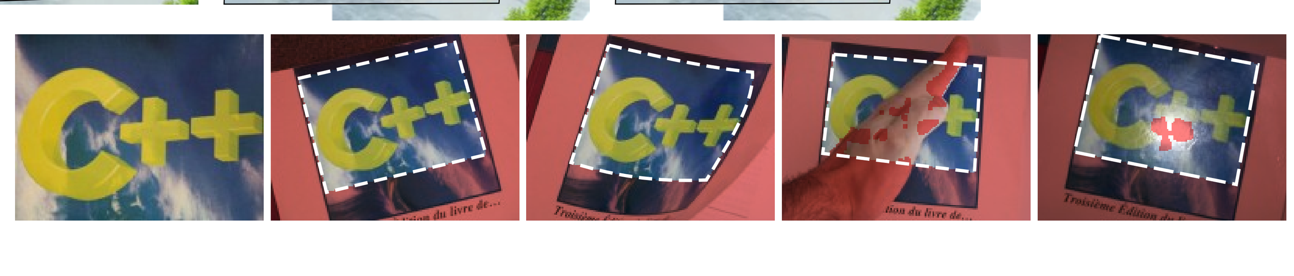
$$\mathcal{T}_\infty(\mathbf{q}) = \begin{cases} \mathcal{T}(\mathbf{q}) & \text{if } \mathbf{q}\in\Omega_{\mathcal{T}} \\ \beta & \text{otherwise}\end{cases}$$



Experimental Results







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