2D Image Registration summary

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2D Image Registration

- Image Registration
  - **Basic steps in image registration**
  - Criteria of image registration classification
  - Geometric image transforms
  - Image Registration algorithms
  - Non rigid image registration with CNN
- Point cloud registration
  - Point cloud registration algorithms
- Applications of Image Registration
  - image mosaicking
  - Medical image registration
  - subtraction radiography and angiography
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Image registration steps

In the figure below, we design the order of the steps that we mentioned [SNI2017] :

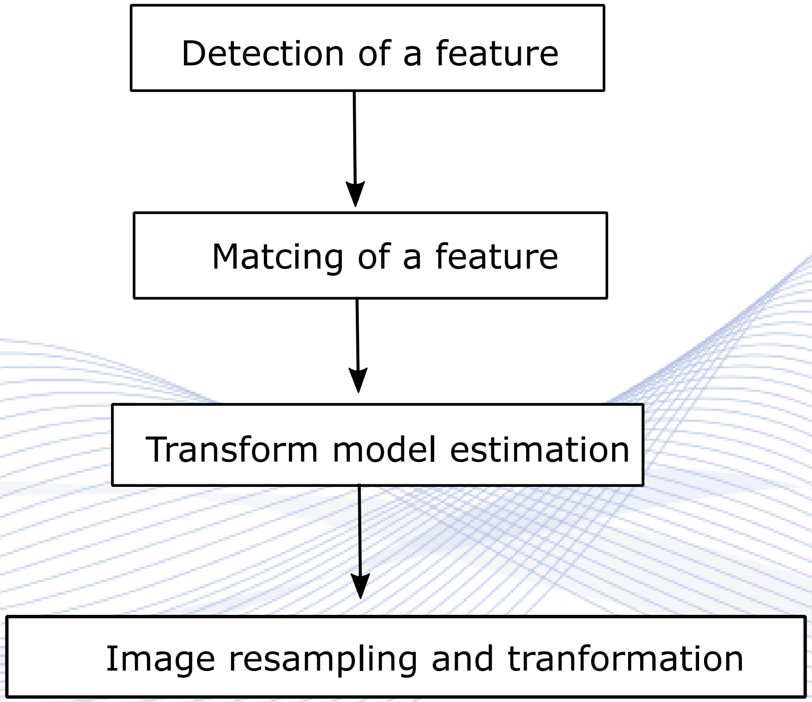

Figure 1. Steps of image registration

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Classification of image registration

Image registration can be classified into 10 categories, according to image registration techniques, which are the following [SNI2017] :

- ***Dimensionality*:** Apart from applying image registration in 2D to 2D and 2D to 3D images, it can also be applied in 3D to 3D images.
- ***Transformation domain*:** Depending on the region of the registration, the transformation can be local or global.
- **Transformation types:** The types of transformation are projective, affine, nonclear and rigid.

Classification of image registration

- **Modalities:** They can be multimodal employing two or more modalities like Magnetic Computed Tomography (CT), Resonance Imaging (MRI) or mono-modal.

- ***Registration Quality's measures*:** For different data or data features, we use many measures.

- ***Registration's parameters*:** Depending on using methods which come from research, we can define the transformation's quality.

- ***Subject of registration*:** In case there are two images with the same subject, we have intra-subject registration. Otherwise, we have inter-subject registration.

Classification of image registration

- ***Object of registration*** **:** Here we have different objects which can be referred as head, knee, thorax, etc.

- ***Source of features*****:** Data's features are names as intrinsic features, while those from the outside are named as extrinsic features. We can also have non-image based features.

- ***Interaction*****:** Depending on the user's interference, this level can be automatic, semiautomatic or interactive.

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Geometric image transforms

Geometric image transforms [PIT2000] :

- ***2D Image translation***:

$$b[i][j] = a[i+k][j+1].$$

- ***2D Image rotation***: If the image point $a(x, y)$ is rotated by θ degrees, its new coordinates (x', y') are given by:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}.$$

Geometric image transforms

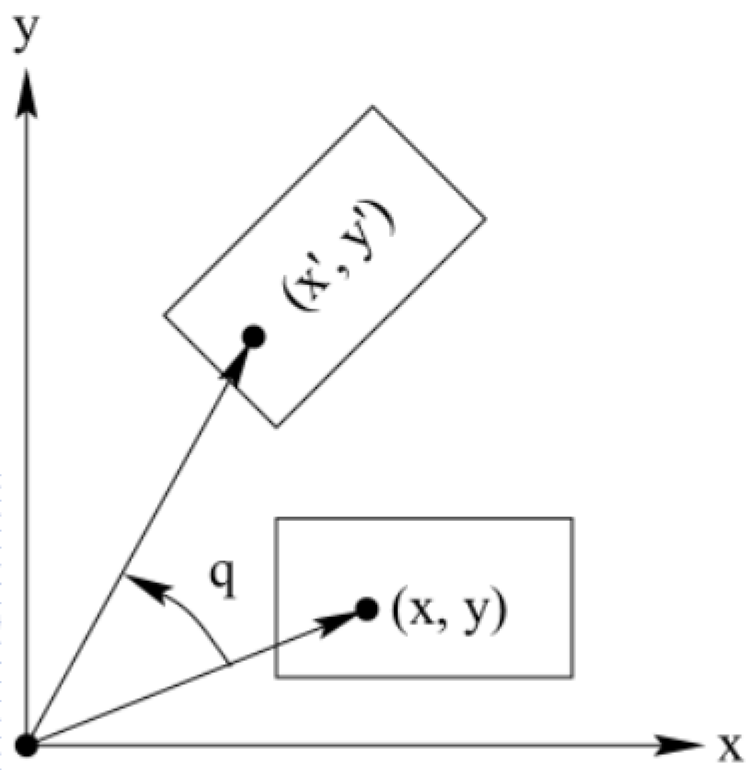

Image rotation.

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Image Registration algorithms

When we have two sets with image data, registration needs to define a transformation (T) which is used to [BHM2003] :

- one image (which is indicated as the floating image) to align it with
- the second image (which is indicated as the reference image).

In order to define the transformation, we have to find a maximum measure of resemblance to the floating image and the transformed reference image.

We can do that with automatic optimization algorithm.

Image Registration algorithms

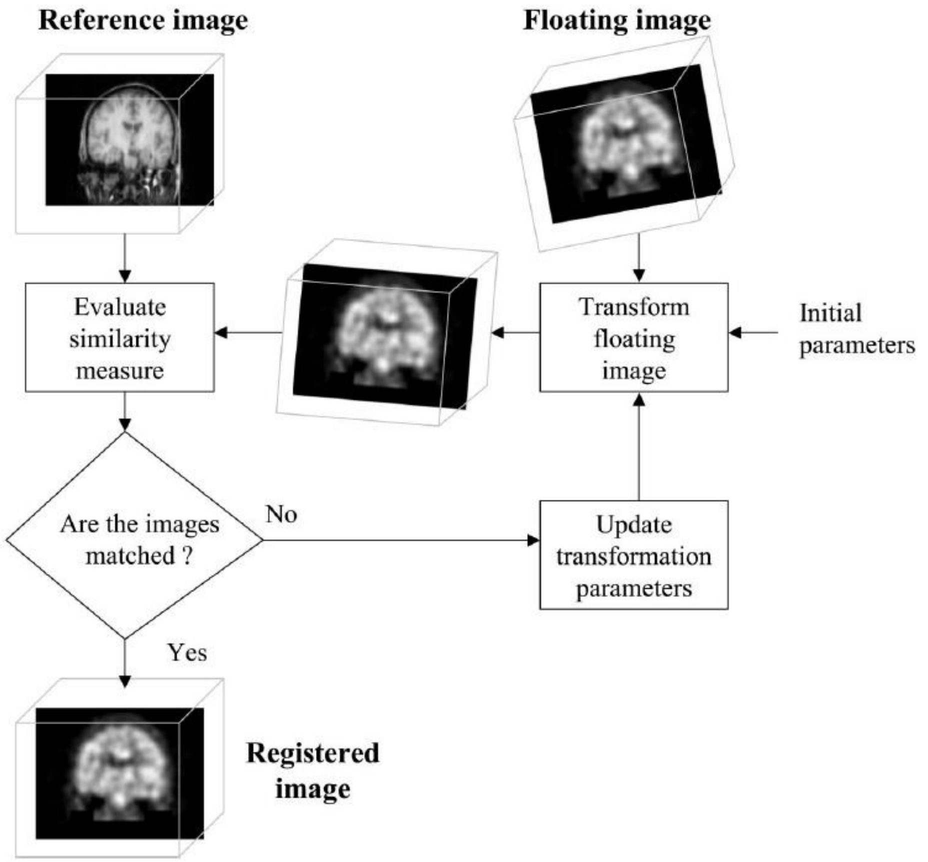

Fig 1. Schematic of a general image registration algorithm. An initial set of transformation parameters is applied to the floating image. The transformed floating image is then compared with the reference image by assessing the similarity between the two images. The algorithm iteratively updates the transformation parameters and reassesses the similarity measure until alignment is achieved.

(from [BHM2003], copyright pending)

Image Registration algorithms

In aligning images, we can use two basic types of transformation [BHM2003] :

- ***Rigid body:*** Where rotation and/or translation are needed. Along the axes, the relative scale factors, most of times, are independently decided.

- ***Non-rigid body:*** There is no rigidity. A non-rigid transformation can become the same to an affine transformation or more complicated ones, where we change the shape either globally or locally.

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Non rigid image registration with CNN

- The registration algorithms which predict images, use convolutional neural networks (CNNs) so they learn [HLY2018]:

  - informative image features
  - a mapping of the features of the learned image
  - spatial transformations which register images in a training dataset

- The training data's quality plays a significant part in the predicting image registration.

Non rigid image registration with CNN

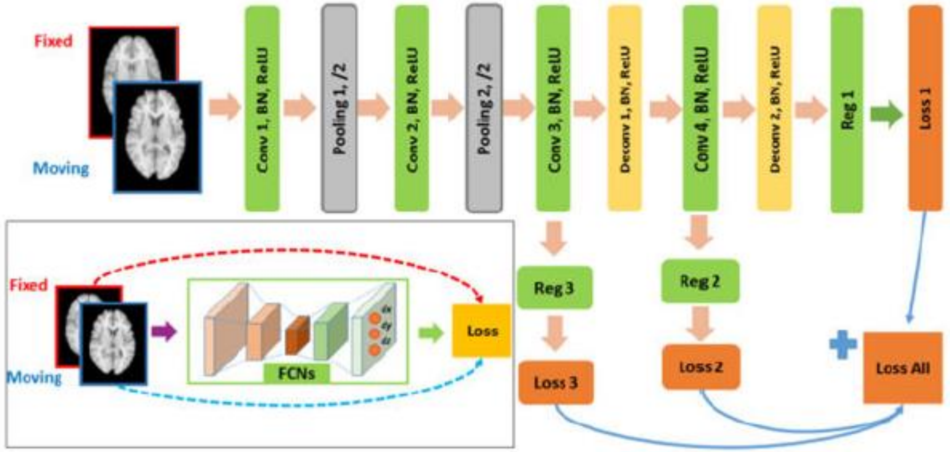

Fig. 1.
Overall architecture of the image registration framework and an example FCNs for voxel-to-voxel regression of deformation fields in a multi-resolution image registration framework.

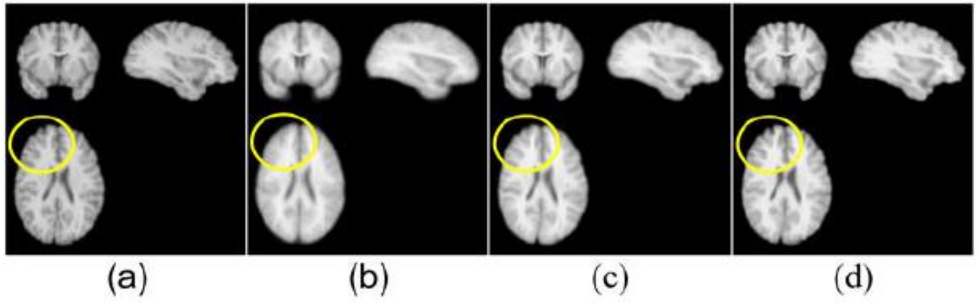

Fig. 2.
Mean brain image before and after registration by different methods. (a) Fixed image, (b) mean of images before registration, (c) mean of registered images by ANTs, (d) mean of registered image by the proposed method.

(from [HLY2018], copyright pending)

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Point Cloud Registration

With ***Point cloud registration*** we are able to find a spatial transformation, like translation, rotation and scaling, which can align two point clouds [WIKI].

- We can find a transformation like this, if we merge many data sets into a catholic constant model and map a new measurement to a well known data set to recognize features.
- For 2D point cloud registration, there is a 2D pixel coordinates as a point set, which is obtained by an image's feature extraction (e.g corner detection).

Point Cloud Registration

- A field of applications in point cloud registration is [WIKI]:

  - autonomous driving,
  - estimation of motion,
  - pose estimation and object detection,
  - manipulation of robots,
  - concurrent mapping and localization,
  - virtual and augmented reality and
  - imaging in medical field.

Point cloud registration algorithms

The first algorithm we will examine the ***Robust point matching (RPM) algorithm.*** [SAC2014]

Steps of the algorithm:

- We have two different point sets, $\{X_j\}$ and $\{Y_k\}$, having an affine transformation $\{A, t\}$, which is bounded by size.
- Then we determine a set of correspondence variables $\{\mathbf{M}_{jk}\}$ which is the match matrix, in a way that:

$$\mathbf{M}_{jk} = \begin{cases} 1 \;\; if\ point\ X_j\ corresponds\ to\ point Y_k \\ 0 \;\; otherwise \end{cases}$$

Point cloud registration algorithms

- This algorithm can determine both the affine transformation and the correspondence at the same time. [SAC2014]

The cost function is:

$$E(\mathbf{M}, t, A) = \sum_{j=1}^{J} \sum_{k=1}^{K} \mathbf{M}_{jk} \left\| X_j - t - AY_k \right\|^2 + g(A) - \alpha \sum_{j=1}^{J} \sum_{k=1}^{K} \mathbf{M}_{jk}$$

Subject to $\forall j \ \sum_{k=1}^{K} \mathbf{M}_{jk} \leq 1, \forall k \ \sum_{j=1}^{J} \mathbf{M}_{jk} \leq 1, \forall jk \in \{0,1\}$ and $g(A) = \gamma(a^2 + b^2 + c^2)$

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Point cloud registration algorithms

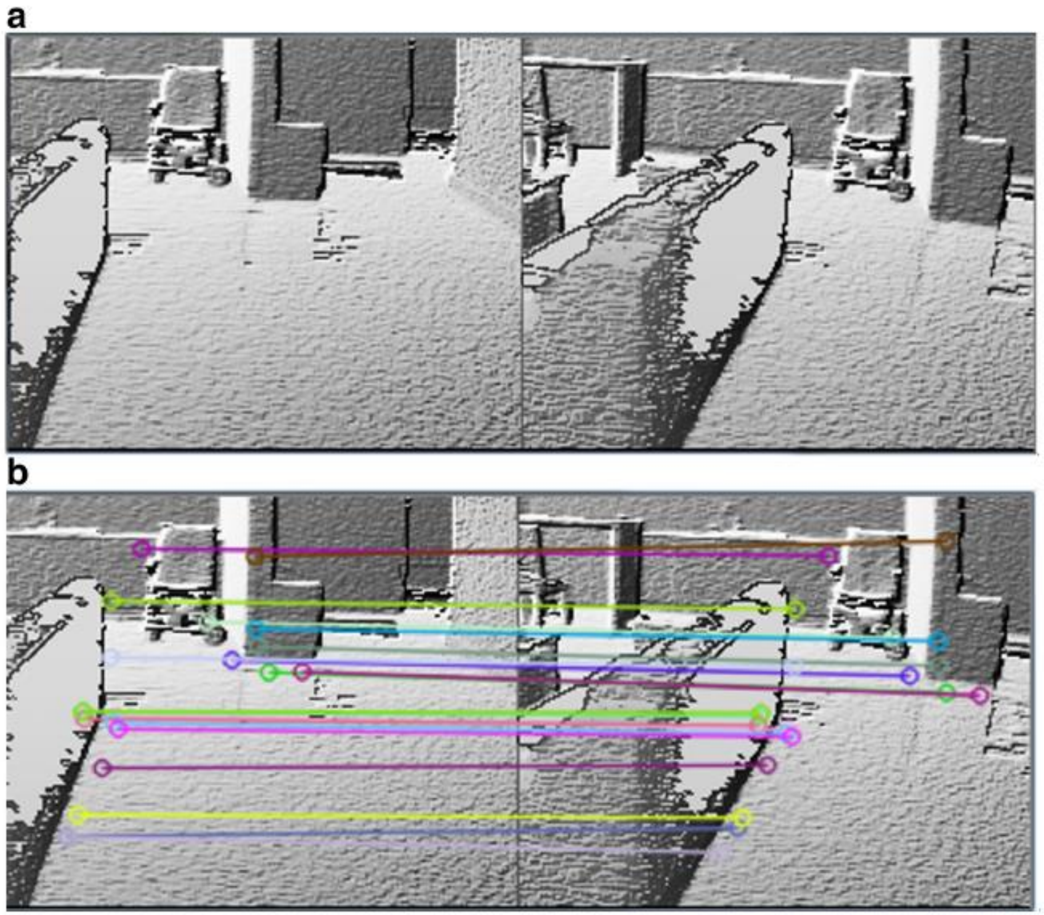

Fig. 4 **a** Two BA images. **b** The matched points of the two BA images by SURF

(from [CYJ2017], copyright pending)

Point cloud registration algorithms

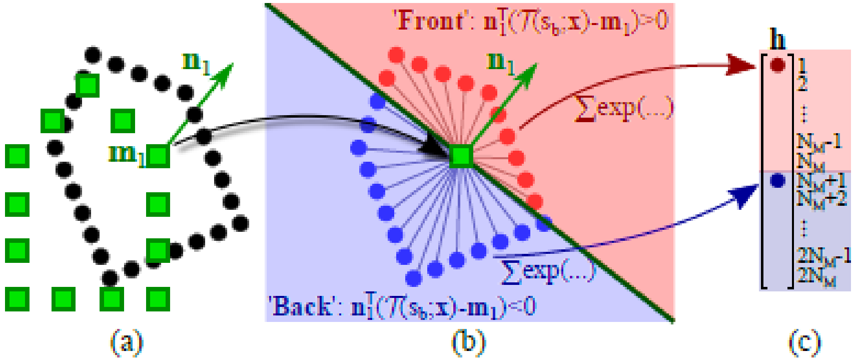

Figure 3. Feature $\mathbf{h}$ for registration. (a) Model points (square) and scene points (circle). (b-c) Weights of $\mathbf{s}_b$ that are on the 'front' or 'back' of model point $\mathbf{m}_1$ are assigned to different indices in $\mathbf{h}$.

(from [JFJ2017], copyright pending)

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Image mosaicking

- Mosaicking of an image is the process of combining two or more overlapped images in a stable or moving scene together into a bigger image [DHA2009].

- That process is essential in order to raise the range of an image's coverage without decreasing its resolution.

- In case there is an interest in an image's area, it is sometimes not possible to include it, because of the limited size of digital images. In this case, overlapped images are acquired, and the images are piecing into a bigger image with the use of image mosaicking [DHA2009].

Image mosaicking

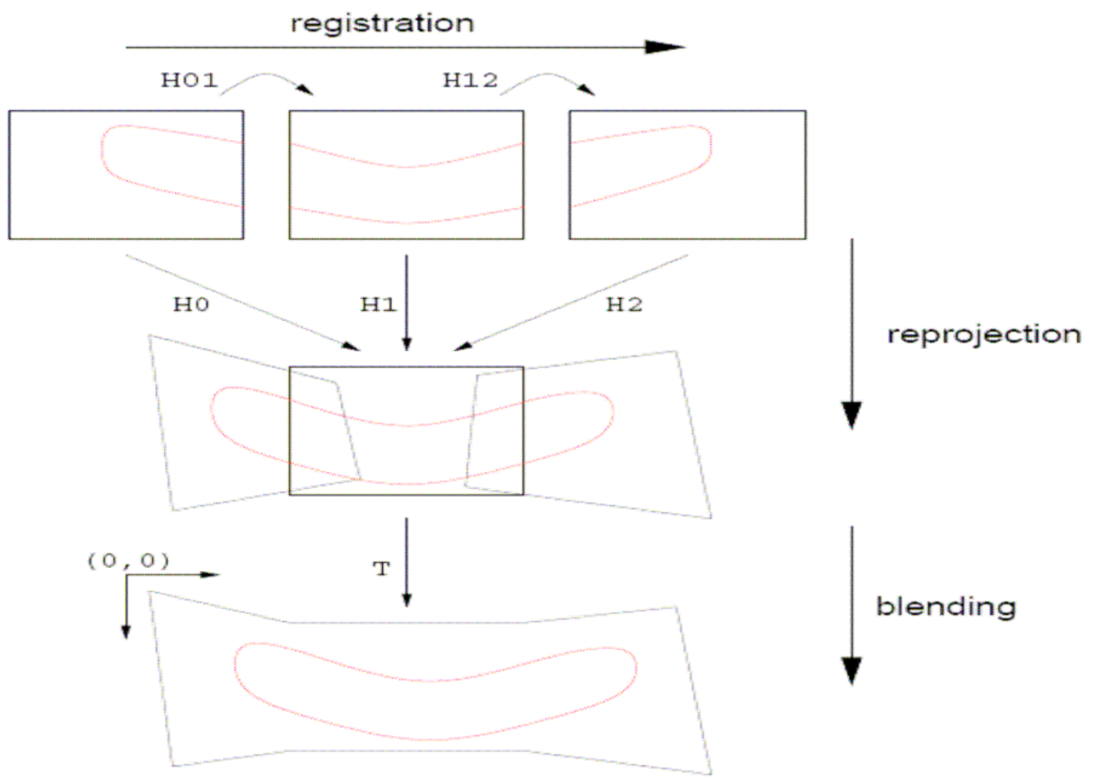


Figure 2. Steps in creating an image mosaic
(from [NTA2005], copyright pending)

Image mosaicking

Now we will show an example of using image registration in order to create mosaic images. More specifically a moving camera takes eight frames showing two people moving in a field.

(from [NTA2005], copyright pending)

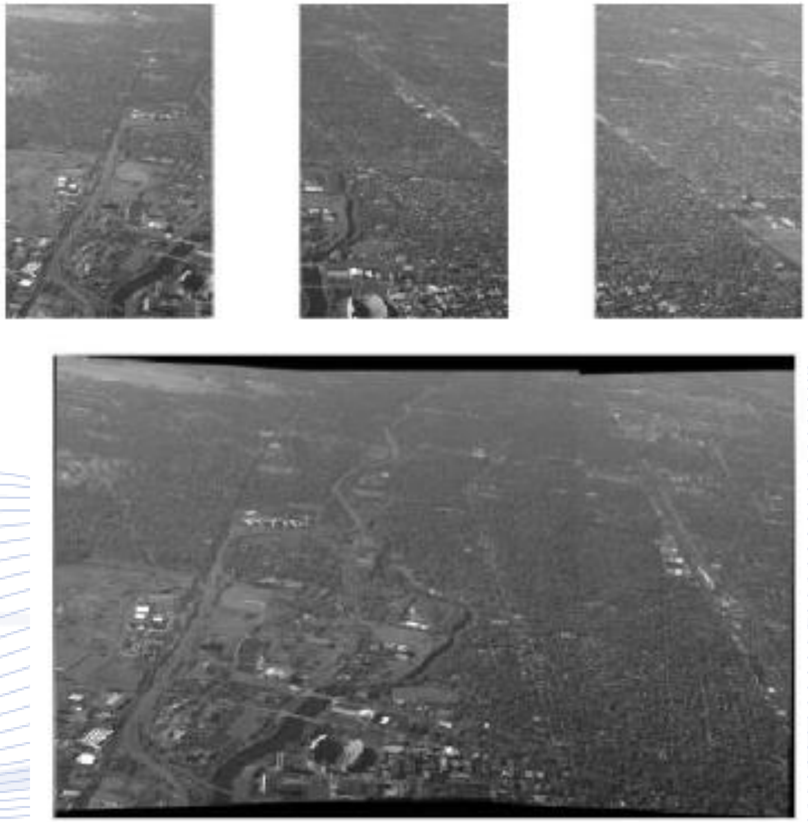
Image mosaicking

Here is the result :

(from [NTA2005], copyright pending)

Image mosaicking

Here is another example of registering and mosaicking 3 images:



(from [NTA2005], copyright pending)

Image mosaicking

- 2D affine transformation for image registration.
- Overlapping image regions are registered and mosaicking.

Image mosaicking

- 2D image registration and mosaicking.

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Medical image registration

Medical image registration is used for clinical circumstances like supervising the progress of a disease, making the diagnosis and preparing the treatment for a patient.

Because of the increasing amount of medical data, we are introduced in MR imaging systems and CT scanning[DPM2000].

Leading radiological imaging ways [DPM2000] ***:***

- Radiographs of raditional projection, with or without subtraction and contrast,
- Images of nuclear medicine projection,
- Ultrasound images

Medical image registration

Main cross-sectional modalities [DPM2000] ***:***

- Magnetic Resonance Imaging (MRI)
- Computed tomography with x-ray (CT)
- Positron Emission Tomography (PET)
- Single Photon Emission Computed Tomography (SPECT).

- With image registration there is a solution in matching images from unlike actions, which vary in the field of view or resolution .

Medical image registration

Registration and display of the combined bone scan and radiograph in the diagnosis and management of wrist injuries Hawkes et al, EJNM 1991

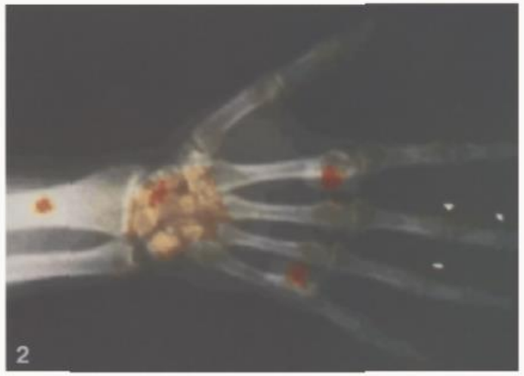

Fig. 1. An example of a scaphoid fracture with a positive radiograph. The focal increased activity on the bone scan is centered exactly at the fracture site

Fig. 2. A bone cyst in the scaphoid is clearly seen in the radiograph. The combined image indicates increased uptake adjacent to the cyst cavity

Fig. 3. A radius fracture with existing osteoarthritis of the carpel joints between scaphoid, trapezium and trapezoid. The radiograph findings were suspicious. Registration confirmed the location of increased isotope uptake at the site of the radial fracture and associated with degenerative changes in the carpal joints while increased uptake over the scaphoid was excluded

(from [CST2010], copyright pending)

Medical image registration

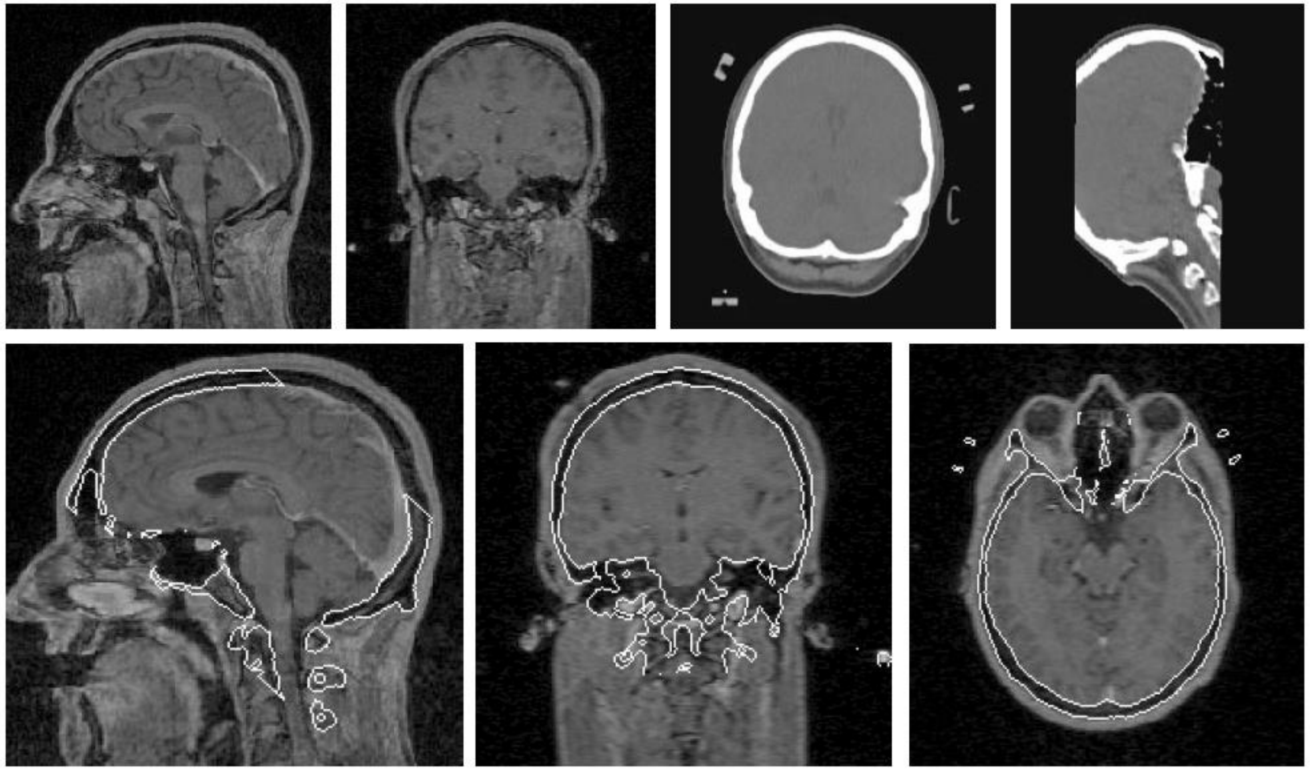

Figure 4. Top row: unregistered MR (left) and CT (right) images. The MR images are shown in the original sagittal plane, and reformatted coronal plane. The CT images in the original oblique plane, and reformatted sagittal plane. Note the different field of view of the images. Bottom panel, MR images in sagittal, coronal and axial planes with the outline of bone, thresholded from the registered CT scan, overlaid. The registration transformation has 10 degrees of freedom, to correct for errors in the machine supplied voxel dimensions and gantry tilt angle.

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(from [DPM2000], copyright pending)

Medical image registration

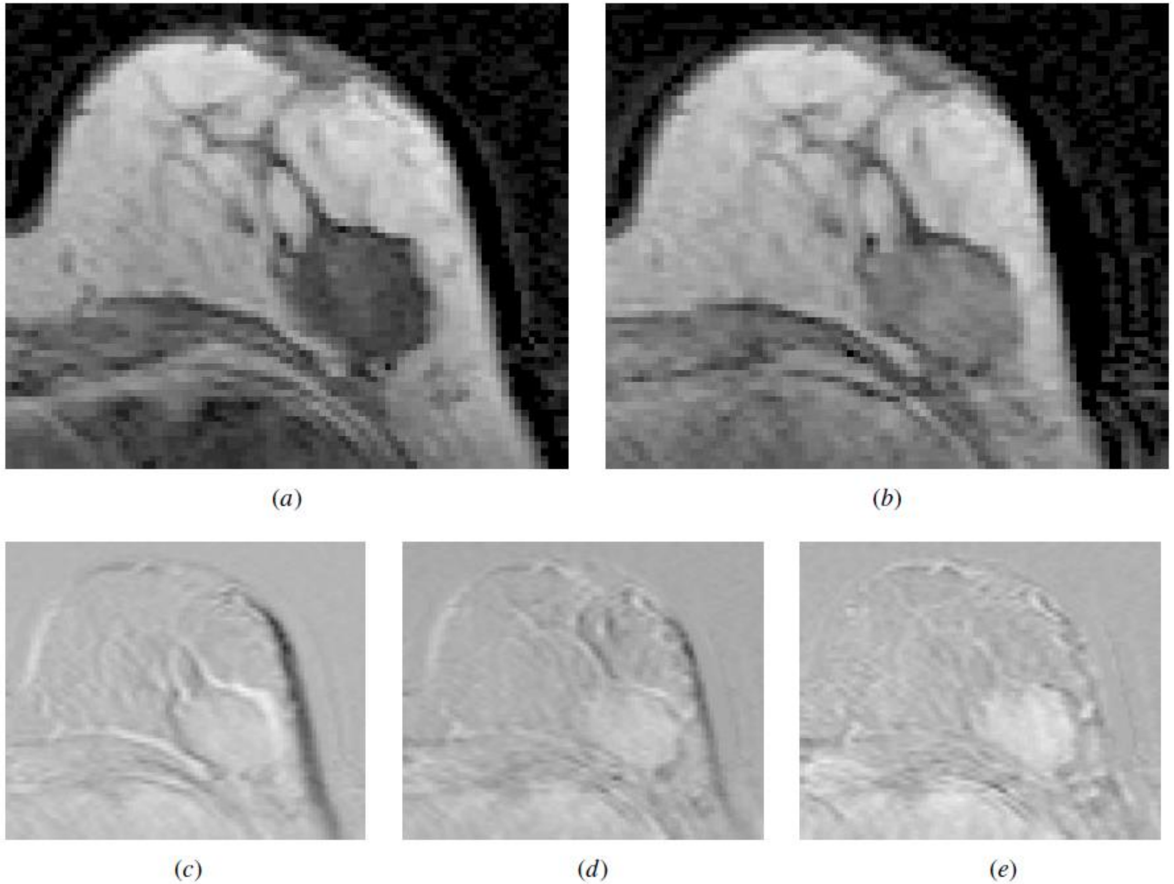
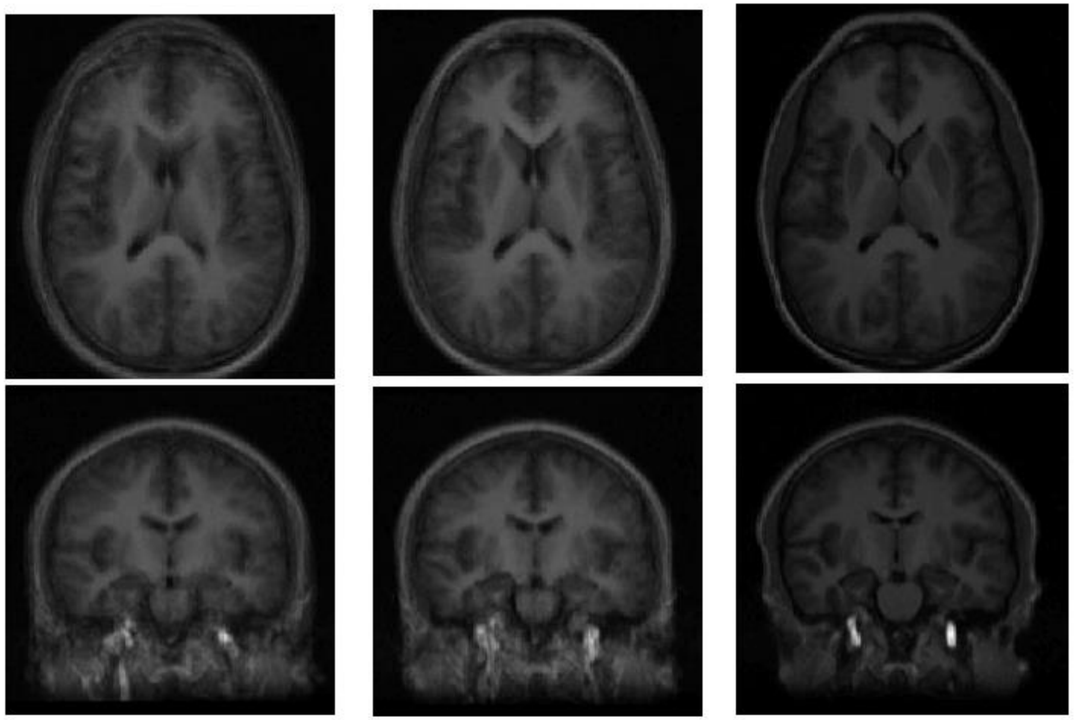


Figure 5. Example slice from (*a*) pre-contrast and (*b*) post-contrast MR mammogram. Without registration, the difference image contains distracting artefacts (*c*). Affine registration results in some improvement (*d*). Non-rigid registration (*e*), using a 10 mm grid of B-spline control points (Rueckert *et al* 1999) results in reduced artefact and improved diagnostic value (Denton *et al* 2000).

(from [DPM2000], copyright pending)

Medical image registration



(*a*) (*b*) (*c*)

Figure 6. Axial (top) and coronal (bottom) slices from average images produced from MR scans of seven different normal controls, registered using (*a*) rigid registration, (*b*) affine registration and (*c*) non-rigid registration using a 10 mm grid of B-spline control points (Rueckert *et al* 1999). In all cases the registration was achieved by maximizing normalized mutual information, as described in section 7.3.3. Note that after rigid registration the average image is quite blurred, indicating that rigid registration does not line up the different brain scans very well. After affine registration, the images are a lot less blurred, especially around basal structures. The non-rigid registration, however, produces the sharpest image, indicating that this sort of algorithm is better at lining up brain features between subjects.

(from [DPM2000], copyright pending)

Medical image registration

The images can be dissociated in time by [DPM2000]:

- seconds (in experiments which are functional),
- minutes (post- and precontrast images),
- weeks (when we monitor tumour growth).

In all these cases, it is preferable to have large reactivity to little changes in the images.

In perfusion or contrast studies, it is preferable to recognize fields that enhance, or quantify great change in a field which we are interested in.

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Subtraction radiography

Radiographic images are essential for dental purposes and can be acquired by radiographic techniques with the risk of having judgement or technical errors[MKI2004].

Such errors are, for example:

- that radiographs can differ in contrast, brightness and acquisition geometry or
- the anatomical or structured “noise,” which depends on the complexity of the anatomical background.

Subtraction radiography

Correction of those errors like the reduction of the noise, can be occurred by ***subtraction radiography*** which leads to the extinction of identical image regions [MKI2004].

- For example, regions that are taken at a different period of time and show the same anatomical element in a series of radiographs.

Image registration in subtraction radiography: [MKI2004]

- Subtraction radiography has the following procedures: registration, normalization and subtraction.
- In order to register the input radiographic image, rotation, translation and scaling are used so the geometrical distortions can be corrected.

Subtraction radiography

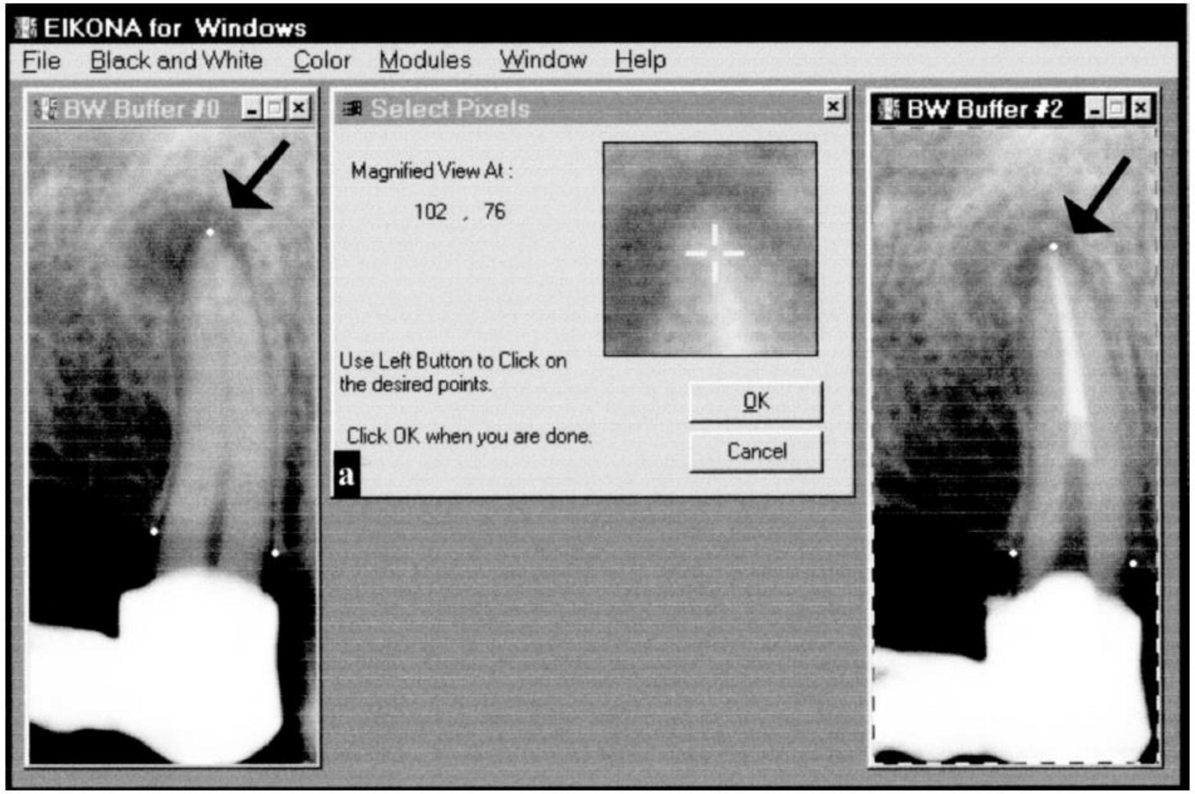
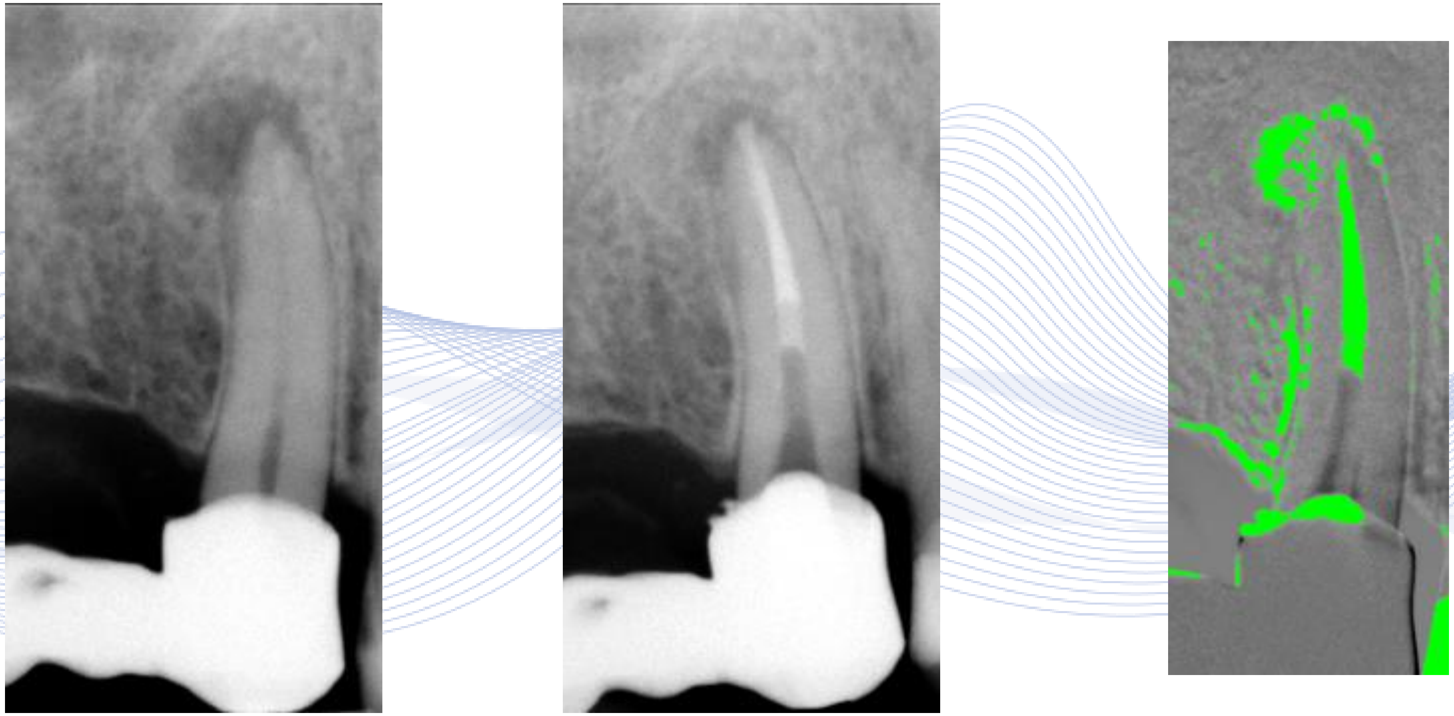


FIG 1. Landmark point selection on two digital periapical radiographic images. The selected landmark points on two digital radiographs are shown as white dots (pointed by arrows). (*a*) A magnification window helps the user to select accurately the corresponding landmark points between the two digital radiographs.

(from [MKI2004], copyright pending)

Subtraction radiography

- For 2D image registration and subtraction we can also use affine mapping transformation: it describes 2D rotation, translation and scaling.



Subtraction angiography

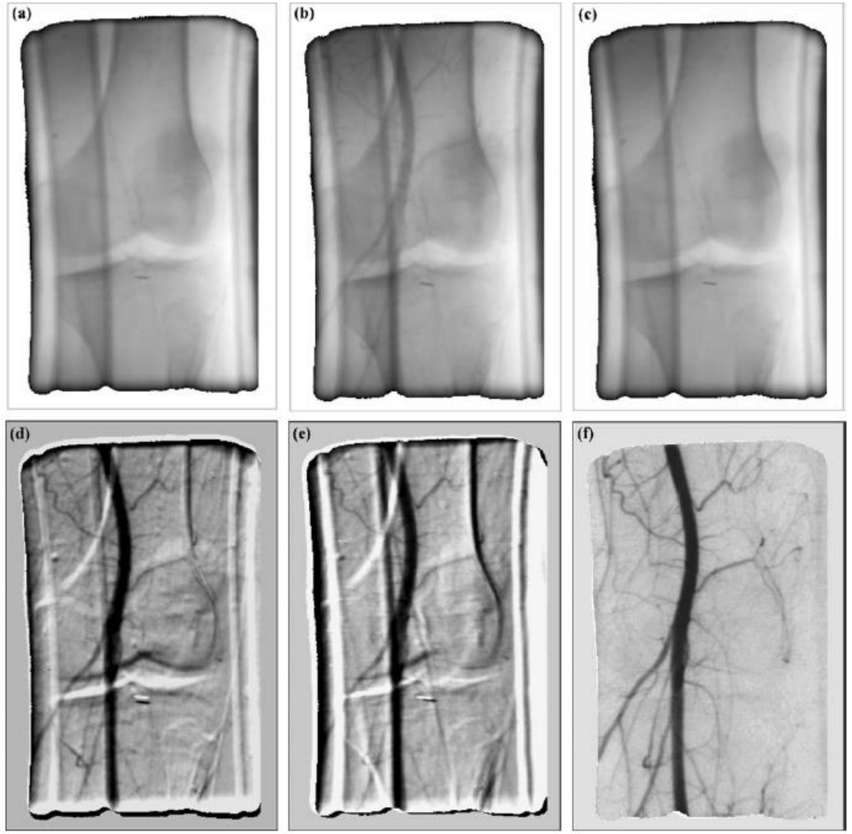


Fig. 3. Registration of a peripheral image sequence showing a knee. (a) The mask image. (b) A contrast image. (c) The registered mask image obtained after application of the proposed approach. (d) The original subtraction of the contrast image from the mask image showing considerable bone-tissue misregistration. (e) Registration using standard pixel-shifting method yielding local correction only. (f) The registration result using the proposed approach. Most of the artifacts have disappeared.

(from [BNM2001], copyright pending)

Subtraction angiography

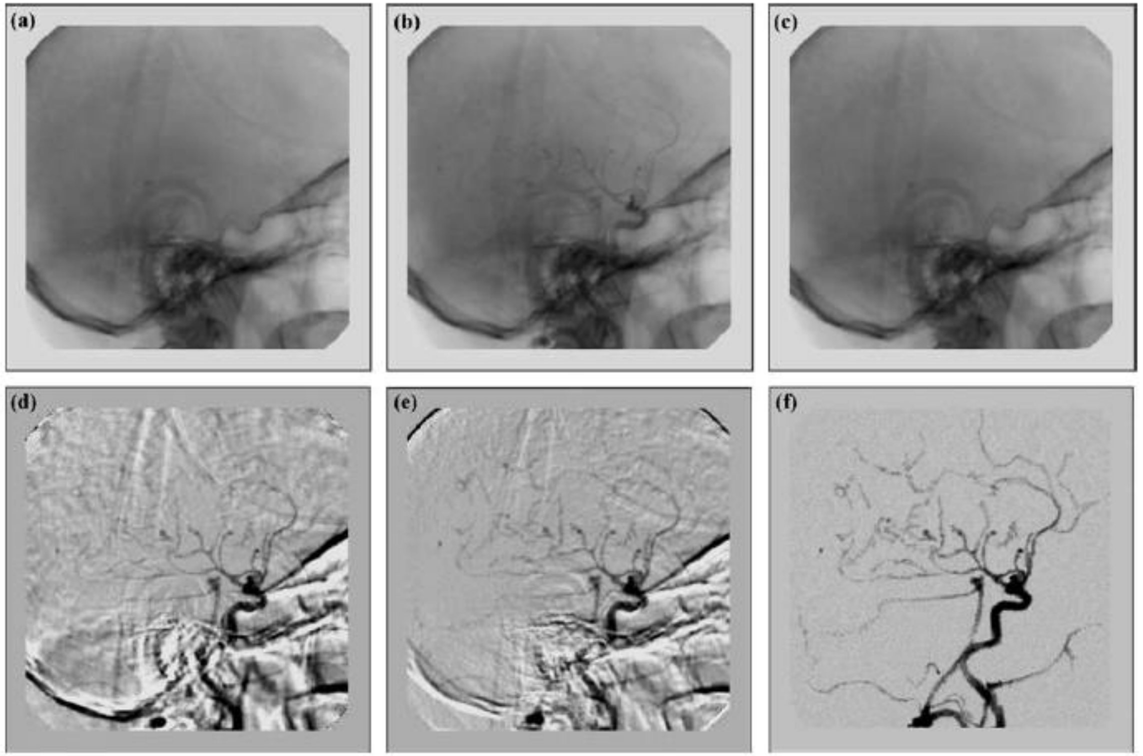


Fig. 4. Registration of a cerebral image sequence. (a) The mask image. (b) A contrast image. (c) The registered mask image obtained after application of the proposed approach. (d) The original subtraction of the contrast image from the mask image showing considerable bone-tissue misregistration. (e) Registration using standard pixel-shifting method yielding local correction only. (f) The registration result using the proposed approach. Most of the artifacts have disappeared.

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Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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