In-Class Lab Activity: Image Registration using ITK

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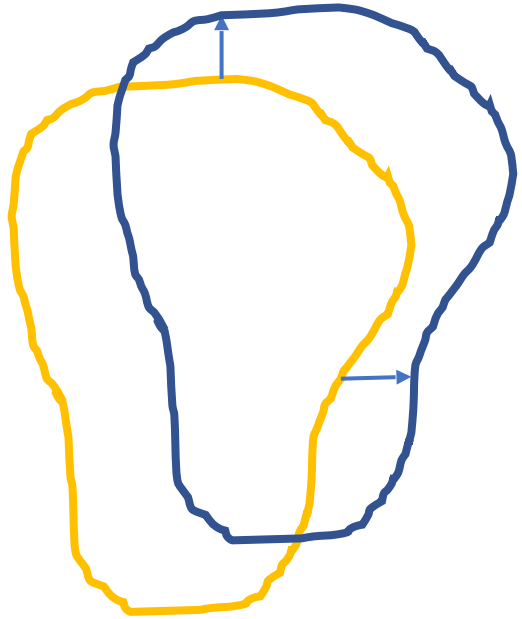
ITK Image Registration

- Itk::ImageRegistrationMethodv4
  - SetFixedImage(ImageType): Set fixed input image
  - SetMovingImage(ImageType): Set moving input image
  - SetInitialTransform(TransformType): Set transform for fixed image (can be identity transform)
  - SetMovingInitialTransform(TransformType): Set initial transform for moving image, type of transform determines the type of registration (can be identity transform)
  - SetMetric(MetricType): Set the metric for registration
  - SetOptimizer(OptimizerType): Select optimizer for registration
  - SetNumberOfLevels(int): Number of scale spaces used for registration [1]
  - SetShrinkFactorsPerLevel(Array): Size factor for each scale space [1]
  - SetSmoothingSigmasPerLevel(Array): Smoothing for each scale space [0]

2D Translation Transform

- Itk::TranslationTransform<double, 2>
  (allows translation in x- and y-dimension)
  - GetNumberOfParameters(): Returns the number of modifiable parameters (2)
  - SetParameters(double[2]): Set x-, and y-translation



Mean Squares Metric

- itk::MeanSquaresImageToImageMetricv4
- Calculates similarity between two images using the mean squared error
- Use SetMetric() function of registration method object to set this metric

$$\mathrm{MSE} = \frac{1}{N}\sum_{\forall x}\left(I_f(x) - I_m(x)\right)^2$$

Gradient Descent Optimization

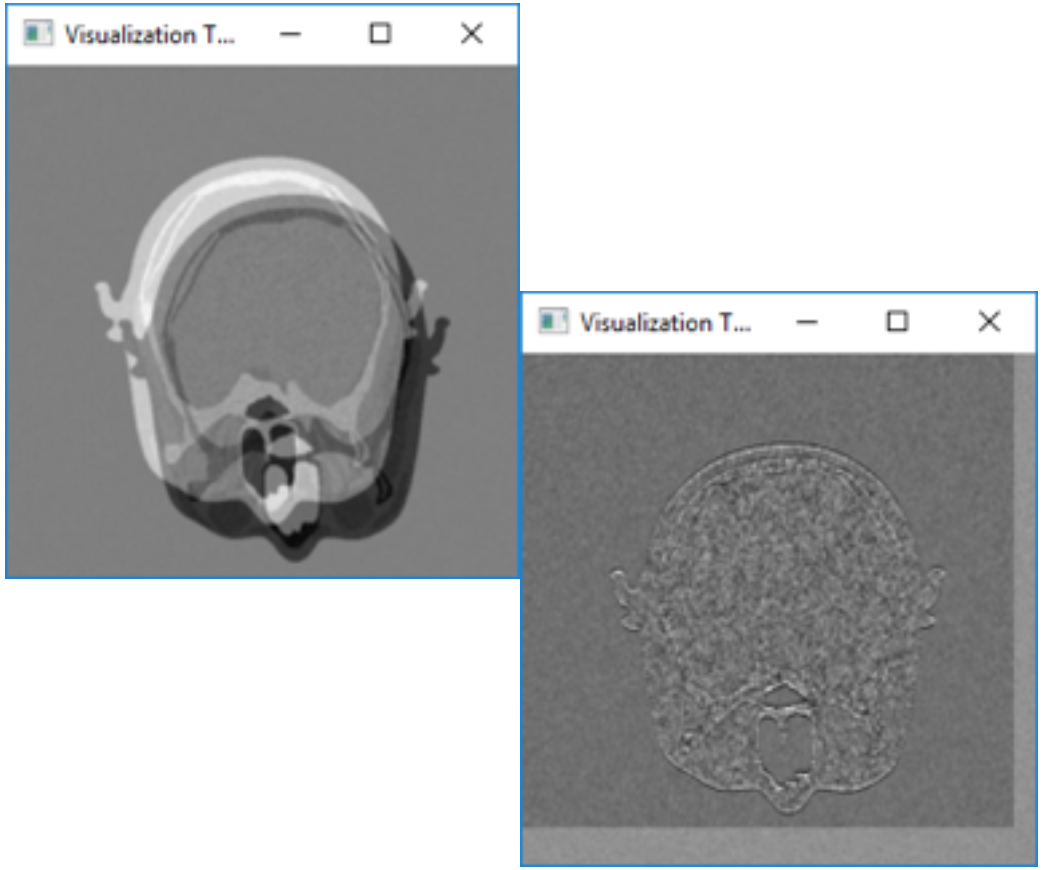
- itk::RegularStepGradientDescentOptimizerv4<double>
  (Calculates the gradient of the cost function using local sampling and steps into the direction of the negative gradient)
  - SetLearningRate(double): Determines the initial step size [4]
  - SetMinimumStepLength(double): Stopping criterion [0.001]
  - SetRelaxationFactor(double): Step size reduction after sudden gradient direction change [0.5]
  - SetNumberOfIterations(int): Stopping criterion [200]

Postprocessing

- itk::ResampleImageFilter
  - SetInput(ImageType): Original moving image
  - SetTransform(TransformType): Estimated transform after registration
  - SetUseReferenceImage(bool): Use spatial reference from fixed image [true]
  - SetReferenceImage(ImagType): Fixed image
  - SetDefaultPixelValue(PixelType): Pixel value for pixels outside the FOV [0]
- itk::SubtractImageFilter
  - SetInput1(ImageType): FixedImage
  - SetInput2(ImageType): Output of resample filter

Exercise 2 [06_MSETranslationRegistration]

1. Read moving and fixed image:
   - head_fix.png
   - head_mov.png
2. Perform 2D translation registration
3. Display the difference between the original fix and moving images
4. Display the difference after registration



2D Affine Transform

- itk::AffineTransform
  - Translation in x- and y-direction
  - 2D Rotation
  - Isotropic and anisotropic scaling
  - Shear transformation

Mutual Information Image Metric

- itk::MutualInformationImageToImageMetric
  - Commonly used for multi-modality registration (e.g. MRI / CT)
  - Larger value corresponds to higher similarity between images

Evolutionary Optimizer

- itk::OnePlusOneEvolutionaryOptimizer
  - SetMaximumIteration(int): Set number of iterations [5000]
  - SetNormalVariateGenerator(RandomGeneratorType): Use itk::Statistics::MersenneTwisterRandomVariateGenerator as random number generator
  - SetInitialRadius(double): Initial step size [1.0]
  - MaximizeOn(): Use this to maximize metric value for mutual information metric

Postprocessing

- itk::CheckerBoardImageFilter
  - Combines moving and fixed image by alternatingly displaying blocks of each image in a checkerboard pattern
  - SetInput1(ImageType): FixedImage
  - SetInput2(ImageType): MovingImage

Exercise 3 [07_MIAffineRegistration]

1. Read moving and fixed image:
   - head_affine_fix.png
   - head_affine_mov.png
2. Perform 2D affine registration using mutual information and evolutionary optimizer
3. Display pre- and post registration results using the checkerboard filter

Deformable Registration

- itkDemonsRegistrationFilter
  - AddObserver(itk::IterationEvent(), ObserverType): Allows tracking of the registration progress
  - SetFixedImage(ImageType): Fixed image
  - SetMovingImage(ImageType): Moving image
  - SetSmoothUpdateField(bool): Activate displacement field smoothing [true]
  - SetNumberOfIterations(int): Number of iterations [500]
  - SetStandardDeviations(double): Controls amount of smoothing [1.0]

Preprocessing: Histogram Matching

- itk::HistogramMatchingImageFilter
  - SetInput(ImageType): Original moving image
  - SetReferenceImage(ImageType): Original fixed image
  - SetNumberOfHistogramLevels(int): Number of histogram bins [1024]
  - SetNumberOfMatchPoints(int): Number of match points [7]
  - ThresholdAtMeanIntensityOn()

```
class CommandIterationUpdate : public itk::Command
{
public:
    using Self = CommandIterationUpdate;
    using Superclass = itk::Command;
    using Pointer = itk::SmartPointer<Self>;
    itkNewMacro(Self);

protected:
    CommandIterationUpdate() {};

public:
    using OptimizerType = itk::OnePlusOneEvolutionaryOptimizer;
    using OptimizerPointer = const OptimizerType   *;

    void Execute(itk::Object *caller, const itk::EventObject & event) override
    {
      Execute((const itk::Object *)caller, event);
    }

    void Execute(const itk::Object * object, const itk::EventObject & event) override
    {
      auto optimizer = dynamic_cast< OptimizerPointer >(object);
      if (!itk::IterationEvent().CheckEvent(&event)) return;
      std::cout << optimizer->GetCurrentIteration() << optimizer->GetValue() <<
        optimizer->GetCurrentPosition() << std::endl;
    }
};
```

Exercise 4 [08_DeformableRegistration]

1. Read moving and fixed image:
   - liver_exp.png
   - liver_insp.png
2. Perform histogram matching
3. Perform deformable registration and display status in each iteration
4. Display pre- and post registration results using difference filter
5. Display intermittent results during registration using the difference filter and VTK