School of Medicine
FACULTY OF MEDICINE AND HEALTH

UNIVERSITY OF LEEDS

Motion compensated reconstruction in STIR 2.4

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Source Code Dissemination

Motion Incorporated Reconstruction with regularisation (MCIR-OSL-MRP)
Image Based Motion Correction with regularisation (RTA-OSL-MRP)

MCIR-OSL-MRP equation:

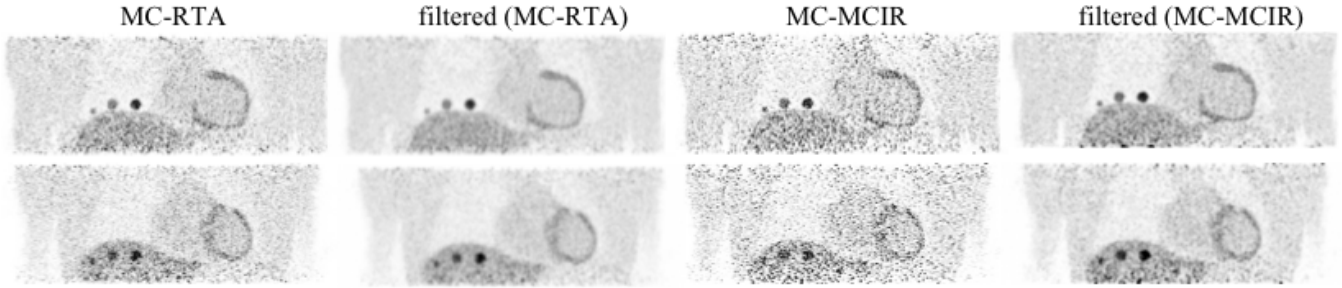
$$\Lambda_v^{(s+1)} = \Lambda_v^{(s)} \frac{1}{\sum_{b\in S_{l,g}} \sum_{\acute{v}} \widehat{W}^{-1}_{\acute{v}g\to v} P_{\acute{v}b} A_{bg} + \beta \nabla_{\Lambda_v} E_v^{(s)}} \sum_{b\in S_{l,g}} \sum_{\acute{v}} \left(\widehat{W}^{-1}_{\acute{v}g\to v} P_{\acute{v}b} \frac{Y_{bg}}{\sum_{\tilde{v}} P_{b\tilde{v}} \sum_{\breve{v}} \widehat{W}_{\breve{v}\to\tilde{v}g} \Lambda_{\breve{v}}^{(s)} + \frac{B_{bg}}{A_{bg}}} \right)$$

Tsoumpas et al (2013) Phys Med Biol

Relevant Publications

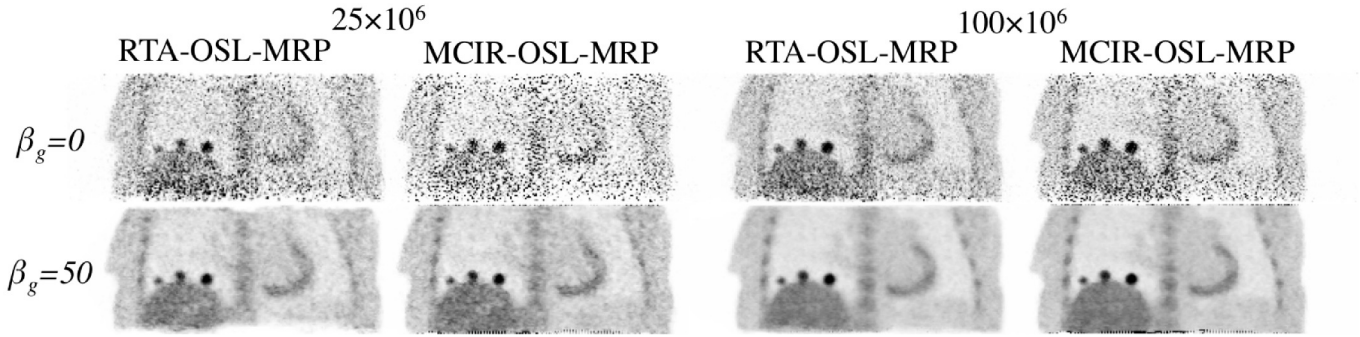
- Image Based Motion Correction
- Motion Correction Within Reconstruction

Polycarpou et al (2012) Medical Physics

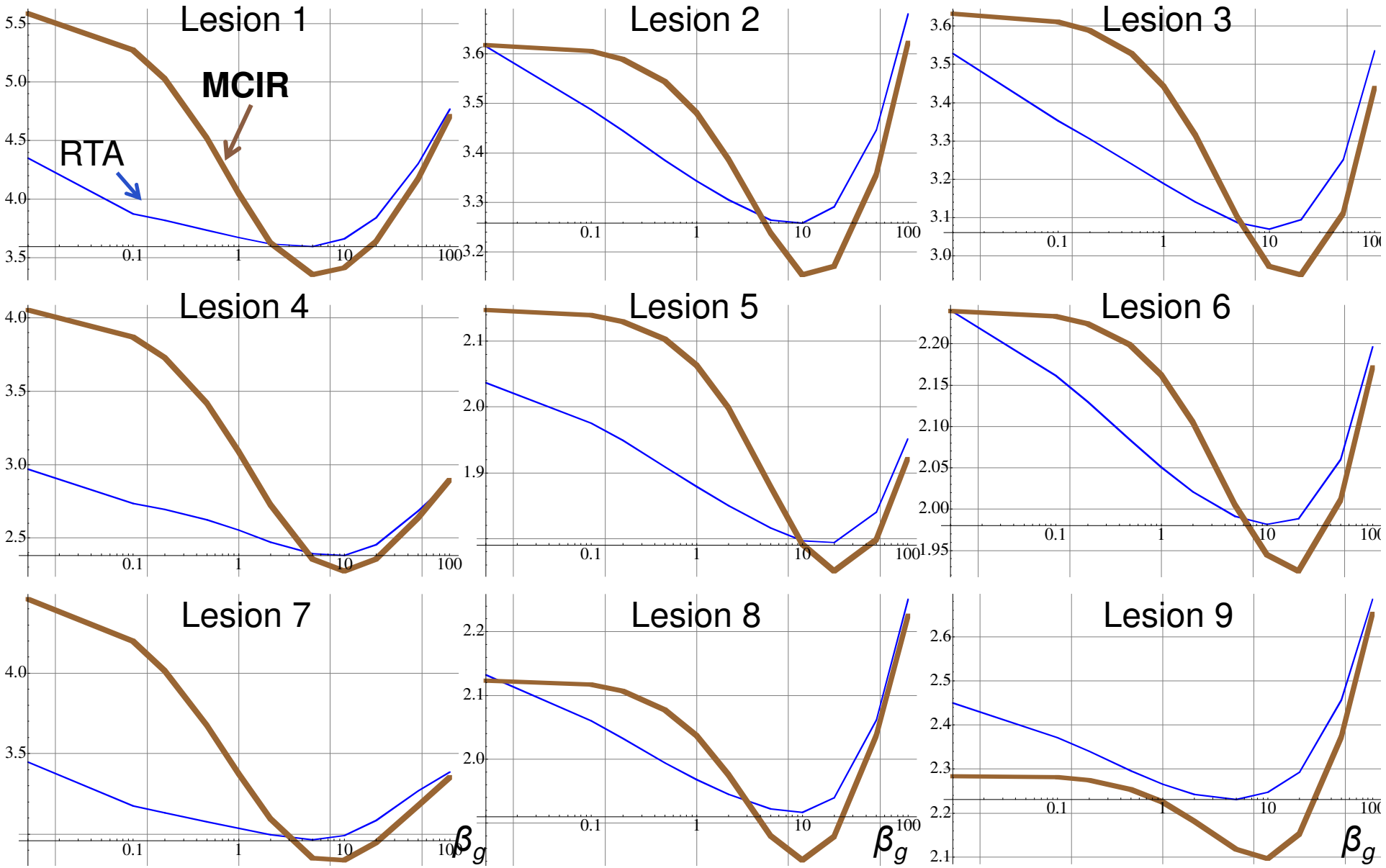


- Regularised Motion Correction

Tsoumpas et al (2013) Phys Med Biol



Regional Root Mean Square Error versus penalisation weight



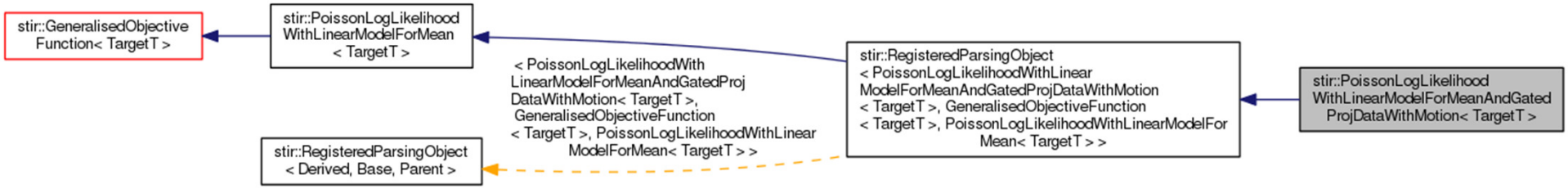
Tsoumpas et al (2013) Phys Med Biol

Transformation

```
VoxelsOnCartesianGrid<float>
warp_image(const shared_ptr<DiscretisedDensity<3,float> > & density_sptr,
           const shared_ptr<DiscretisedDensity<3,float> > & motion_vector_sptr)
{
    const DiscretisedDensityOnCartesianGrid <3,float>*  density_cartesian_sptr =
        dynamic_cast< DiscretisedDensityOnCartesianGrid<3,float>* > (density_sptr.get());
    const BasicCoordinate<3,float> grid_spacing=density_cartesian_sptr->get_grid_spacing();
    const CartesianCoordinate3D<float> origin=density_cartesian_sptr->get_origin();

    const BSpline::BSplinesRegularGrid<3, float> density_interpolation(*density_sptr, linear);

    BasicCoordinate<3,int> min;   BasicCoordinate<3,int> max;
    const IndexRange<3> range=density_sptr->get_index_range();
    if (!range.get_regular_range(min,max))
        error("image is not in regular grid.\n");
    const BasicCoordinate<3,int> out_min=min;    const BasicCoordinate<3,int> out_max=max;
    const IndexRange<3> out_range(out_min,out_max);
    VoxelsOnCartesianGrid<float> out_density(out_range,origin,grid_spacing);

    BasicCoordinate<3,int> c;
    BasicCoordinate<3,double> d, l;
    for (c=min; c<=max; ++c)      {
        l = static_cast<double> ((*motion_vector_sptr)[c]/grid_spacing);
        d = c + l;
        out_density[c] = density_interpolation(d);
    }
    return out_density;
```

New Classes in STIR 2.4

```
GatedDiscretisedDensity
GatedProjData
MotionField
MotionVectors
TimeGateDefinitions
PoissonLogLikelihoodWithLinearModelForMeanAndGated
ProjectionDataWithMotion
```



How to work with the RTA?

Utility:

```
warp_and_accumulate_gated_images
                                    <output filename>
                                    <filename prefix>
                              <motion vectors prefix>
```

$$\Lambda_v = \frac{1}{G}\sum_{g}\sum_{\acute{v}} W^{-1}_{\acute{v}g\to v}\,\Lambda_{\acute{v}g}$$

How to run MCIR?

Normal Reconstruction: `OSMAPOSL <OSMAPOSL.par>`

```
OSMAPOSLParameters :=
objective function type:=
PoissonLogLikelihoodWithLinearModelForMeanAndGatedProjectionDataWithMotion
PoissonLogLikelihoodWithLinearModelForMeanAndGatedProjectionDataWithMotion
Parameters:=
input filename prefix := INPUT
; Input multiplicative factors (norm*attenuation). Suffix of each file is _g#
normalisation sinograms prefix:= ATTENNORMFACTORS
; Input additive term (randoms + scatter). The suffix of each file is _g#
additive sinograms prefix := scaled_attcor_upsampled_scatter_estimation
Gate Definitions filename := MOTION.gdef
; Motion Vectors in image file format with suffix: _g#d%
Motion Vectors filename prefix := MOTION
Reverse Motion Vectors filename prefix := INVERTEDMOTION
end
PoissonLogLikelihoodWithLinearModelForMeanAndGatedProjectionDataWithMotion
Parameters:=
output filename prefix := MOTIONCORRECTEDIMAGE
END:=
```

Data Preparation

- Multiple Files (one for each position): Emission sinogram, Multiplicative corrections (attenuation, normalisation), additive corrections (scatter, randoms), motion vectors, and gate definitions filename.

- Sinograms for each position: Standard suffix _g#, e.g. *sinogram_g1.hs* is the header of the position 1. Needs a definition file, e.g. *sinogram.gdef*

- Images: Similar suffix _g#. Needs a definition file, e.g. *image.gdef*

- Motion Vectors: Suffix _g#d%, e.g. *motion_g1d1.hv* is the header of the motion corresponding to the position 1 and 1st direction. Needs also a definition file, e.g. *motion.gdef*. The image has exactly the same characteristics as the reconstructed PET image.

Additional Notes

- Both RTA & MCIR use the same warping routines
- MCIR requires two motion fields: forward motion fields and the backward motion fields (i.e. the same as used in RTA).
- It is important that the forward and backward projectors are consistent with each other, if not the result might not converge to a solution.
- Different gate duration could be accounted for by normalizing for the time duration
- MCIR at late iterations may have a small number of voxels very high value
- If you wish to estimate motion there is a free software package at KCL compatible with STIR IO: http://www.isd.kcl.ac.uk/internal/hyperimage
- Realistic gated simulated data are available for free: http://www.isd.kcl.ac.uk/pet-mri/simulated-data/

More information

- User's Guide Documentation
- Reconstruction Test Package (recon_test_pack)
- C++ code and Doxygen documentation
- Relevant publications: Polycarpou *et al* (2012) Med Phys,
  Tsoumpas *et al* (2013) PMB

Next Steps

- **More robust testing**: Currently the tests are performed based on basic tests.
- **Regularisation:** with Quadratic Priors
- **OSSPS**: Needs further debugging as it seems the current settings do not reconstruct the motion compensated image.
- **Scatter Estimation**: Assumed to have it already estimated prior to reconstruction.
- **Out of the field of view motion**
- **Rigid motion** for brain imaging
- Combine **Motion** and **Kinetic Modelling**
- **SPECT** & **motion compensated reconstruction**

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PhD Studentship

Motion correction of clinical PET/CT data using motion information from MRI

Deadline: 6/1/2014

Applications: fmhgrad@leeds.ac.uk

Inquiries: c.tsoumpas@leeds.ac.uk

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KING'S College LONDON

SEVENTH FRAMEWORK PROGRAMME

HYPER

SUBLIMA

STIR

GRANTS:

HYPERimage EU FP7: 201651
SUBLIMA EU FP7: 241711