High Resolution Research Tomograph
U S E R   C O M M U N I T Y

HRRT_U 1.0 Specifications

1. General

HRRT_U software is a HRRT User Community release. Its installation should not replace or modify any file of the original CPS distribution. The new software is installed in a different directory (c:\cps\Users_SW) and "_u" is added to the program names for programs already existing in the original distribution (e.g. e7_sino_u for e7_sino).

The main purpose of this version is the integration in a cluster environment of:

- Inki's fast reconstruction (hrrt_osem3d),
- fast pre-processing (e7_sino_u, gendelays),
- Component-Based Normalization (norm_process).

This version also corrects reported problems for short frame histogramming (lmhistogram_u).

2. Fast Inki Reconstruction: hrrt_osem3d

Tag	Switch	Description
S2.1	-W 3	Reconstruction using hrrt_osem3d should give the same image as the standard cluster reconstruction using the same input files and the OP-OSEM scheme.
S2.2	-B 0,0,0	hrrt_osem3d supports resolution recovery (PSF) as described in (1).[1]
S2.3	-s	hrrt_osem3d supports a new scatter format (2D segment followed by scale factors) described in S3.1. It automatically detects the format (no new switch) and extends the 2D scatter into 3D span9 or span3 using Inverse Single Slice Rebinning (ISSRB) and applying the scale factors.
S2.4	-d	hrrt_osem3d supports coincidence histogram (.ch) as input for smoothed randoms. It automatically detects the format (no new switch) and computes the smoothed randoms using Inki's optimized gen_delays from the .ch file and saves it in a temporary file for 32bit OS (2GB) and stores it in memory for 64bit OS (4GB RAM or more) only.
S2.5	-W 2	hrrt_osem3d supports ANW schemes (Attenuation Normalization Weighted) to reconstruct data without attenuation (e.g. point source) as supported by the original cluster reconstruction code. The missing attenuation is replaced by 1 and scatter by 0.
S2.6	-M 328	HRRT scanner model (same as –M 999)
S2.7	-M 3281	Low Resolution mode 1: 2mm bin size, 2.4375mm plane separation, 103 planes.

---

[1] Remember to add reference 1.

S2.7	-M 3282	Low Resolution mode2: 2.4375mm bin size and plane separation, 103 planes.
S2.8	-D dir	Temp directory to store normfac and smoothed randoms (e.g patient directory) for 32bit OS. The smoothed random sinogram created from .ch file is deleted at the end of the reconstruction.
S2.9	N/A	Use a LookUp Table (LUT) for Nearest Neighbor(NN) rebinning to avoid rounding mismatch between random smoothed sinogram that may be created with 64bit executable (hrrt_osem3d) and the normalization created with 32bit executable. The LUT file **hrrt_rebinner.lut** is stored in **c:\cps\users_sw** on the reconstruction server or **c:\cps\cluster_u** on the cluster reconstruction nodes.
S2.10	N/A	Write reconstruction software version and build ID in the image header

Table 1: Tags and descriptions of the hrrt_osem3d specifications.

3. Memory and Disk Space Optimization: e7_sino_u

The new e7_sino_u requires less memory (1.3Gb) than available (2Gb) on common 32-bit windows XP computers, as shown in table 2. The original e7_sino required more than 2GB memory and started swapping when loading the normalization. Its speed also depended heavily on the disk speed, whereas there is no swapping in the new version. e7_sino_u deletes the normalization after using it and does not store the 3D scatter sinogram, which can now be calculated on the fly from the 2D scatter using Inverse Single Slice Rebinning (ISSRB).

A new option -os2d allows to save the scatter in a new compact format (2D segment followed by the scale factors). The scatter is always calculated in span9 (see also lmhistogram_u). The new scatter format is extended on the fly to span9 or span3 by hrrt_osem3d.

<table>
<tr><td colspan="2" align="center">OLD: e7_sino (2.5GB)</td><td colspan="2" align="center">NEW: e7_sino_u (1.3GB)</td></tr>
<tr><td>Action</td><td>Memory Required</td><td>Action</td><td>Memory Required</td></tr>
<tr><td>Load EM</td><td>636MB</td><td>Load EM</td><td>636MB</td></tr>
<tr><td>Load ATN</td><td>1.2GB</td><td></td><td></td></tr>
<tr><td>Load Norm</td><td>1.8GB</td><td>Load Norm</td><td>1.2GB</td></tr>
<tr><td>EM = gapfill(EM*Norm)</td><td></td><td>EM = gapfill(EM*Norm)</td><td></td></tr>
<tr><td></td><td></td><td>Delete Norm</td><td>636MB</td></tr>
<tr><td></td><td></td><td>Load ATN</td><td>1.2GB</td></tr>
<tr><td>im = recon(SSRB(EM))</td><td>1.85GB</td><td>Im = recon(SSRB(EM))</td><td>1.25GB</td></tr>
<tr><td>mu = recon(ATN)</td><td></td><td>mu = recon(ATN)</td><td></td></tr>
<tr><td>s2D = scatter_sim(im,mu)</td><td>1.9GB</td><td>s2D = scatter_sim(im,mu)</td><td>1.3GB</td></tr>
<tr><td>s3D = ISSRB(s2D)</td><td>2.5GB</td><td></td><td></td></tr>
<tr><td>sf= ScaleFactors(ATN,EM,s3D)</td><td></td><td>Sf=ScaleFactors(ATN,EM,ISSRB(s2D))</td><td></td></tr>
<tr><td>Save (sf*S3D)</td><td></td><td>Save (sf*ISSRB(s2D))   or
Save s2D and sf</td><td></td></tr>
</table>

Table 3.1: e7_sino and e7_sino_u memory usage.

3.1 Modified Functions

None.

Tag	Switch	Description
S3.0	Backward compatibility	E7_sino_u should give the same results (with 0.1% difference) that e7_sino when the same inputs and arguments are used.

Table 3.2: Tags and descriptions of the modified functions in e7_sino_u.

3.2 New Functions

Tag	Switch	Description
S3.1	-os2d	New option to output the scatter in compact format: unscaled 2D segment followed by the scale factors. The switch has no argument; the output file name is specified using the same switch (-os) as in e7_sino.
S3.2	-lebr b	New option to specify back and front crystal layer background energy ratio (LBER) that overrides values from GM328.ini. Example: –lber 12.0.
S3.3	-m 3281	Low Resolution mode 1: 2mm bin size, 2.4375mm plane separation
S3.4	-m 3282	Low Resolution mode 2: 2.4375mm bin size and plane separation

Table 3.3: Tags and descriptions of the new functions in e7_sino_u.

4. Cluster Integration: hrrt_osem3d

4.1. clc_u and clq_u

The new clc_u is a modified version of the original cluster service "ClusterServer" to support subclustering and different applications (clcrecon). Only the osem3d application was supported in original versions. The new service is installed using the same service name as the original programs. The user can easily switch from the new to the original programs using the command "clc -U" ("clc_u -U" to switch back to the new programs).

clq_u is a new program to install the queue service "ClusterQueue" which was not part of the original software.

The cluster configuration is stored in c:\cps\cluster_u\ClusterConfig.txt (example below).

```
HOST   reconserver
RAID   reconserver     192.168.1.1
node   node1                                                      192.168.1.11
.
.

node   node8                                                      192.168.1.18
.
```

The file contains two entries for the server (one to specify that it is the server and one for its IP address) and one for each node (IP address).

The Queue configuration is stored in c:\cps\cluster_u\QueueConfig.txt (example below for an 8 node cluster).

> *#!QueueConfig*
> *Recon-Jobs   D:\Recon-Jobs*
> *Jobs-Submitted D:\Recon-Jobs\Jobs-Submitted*
> *Jobs-In-Progress   D:\Recon-Jobs\Jobs-In-Progress*
> *Jobs-Completed   D:\Recon-Jobs\Jobs-Completed*
>
> *ClusterSize.Min   1*
> *ClusterSize.Max   8*
> *ClusterSize.Set 1*

ClusterSize.Max is the number of nodes. ClusterSize.Min and ClusterSize.Set are set to 1 to force the sub-cluster size to 1. Such a cluster can reconstruct eight frames in parallel.

4.1.1 clc_u functions

The functions in table 4 below is used to install clc_u or clq_u and test the services. Refer to keywords document for a complete list of functions

Tag	Switch	Description
S4.1	-v	Print clc/clq version.
S4.2	-I	Install ClusterServer/QueueServer service on the local machine
S4.3	-U	Update ClusterServer/QueueServer on all machines (server and nodes)
S4.4	-V	Print ClusterServer/QueueServer versions

Table 4: Tags and descriptions for cluster integration.

4.2 clcrecon

clcrecon is a modified version of the existing osem3 cluster application to run hrrt_osem3d on a single cluster node. The cluster must be configured in subclusters with a single node per subcluster. If a subcluster has many nodes, only the first node will be used). The application uses two threads: one to execute hrrt_osem3d and one to monitor the reconstruction progress. clcrecon replaces input file paths by UNC paths prior to executing hrrt_osem3d (e.g.: D:\SCS_SCANS is replaced by \\SERVER\SCS_SCANS).

4.2.1 Modified Keywords

Tag	Switch	Description
S4.5	#!clcrecon	First line in job file (instead of #!osem3d).
S4.6	Scatter	3D or new (unscaled 2D and scale factors) scatter file.
S4.7	Delayed	Smoothed random or coincidence histogram (.ch).
S4.8	N/A	Input and output file names are replaced by UNC paths

Table 5: Tags and descriptions of osem3 modified keywords.

 Refer to Cluster Keywords 28-JUL-2008 document for complete list of keywords.

4.3 ClusterServer account configuration

 The reconstruction using clcrecon and hrrt_osem3d is initiated by ClusterServer service. The Service processing account should be set on all nodes to an existing account on the fileserver with read/write access to the data directory D:\SCS_SCANS. See installation procedures for details.

5. Component-Based Normalization (CBN): norm_process

norm_process is an implementation of the CBN method developed by NIH. It computes the crystal efficiencies and a normalization sinogram from the rotating ^{68}Ge rod normalization scan listmode. It requires a much shorter acquisition time (e.g. 1h) than the original direct normalization method (e.g. 32h) when using a new rod.

  The normalization is computed in 2 steps: (i) crystal efficiency, (ii) normalization sinogram in specified span (span 9, span 3, low resolution 2.4mm or 2mm). The default id span9.

The crystal efficiencies are saved to be reused to compute the normalization sinogram of (other) spans.

The input file can be either a 64bit listmode (.l64 extension) or a crystal efficiency file (.ce extension).

If the input is a listmode, the outputs are crystal efficiencies and a normalization sinogram in the requested span (default=9).

If the input is a crystals efficiency, the output is a normalization sinogram in the requested span (default=9).

5.1 Algorithm

  1) Computes the crystal fansums, applying the corrections: (i) live time, (ii) radial and axial geometric effects, (iii) solid angle; for each LOR.

  2) Computes the crystal efficiencies iteratively from the fansum and saves the crystal efficiencies (.ce file extension).

  3) Computes the normalization sinogram in requested span from the crystal efficiencies and saves it.

5.2 Geometric Profiles

The axial and radial geometric profiles are stored in a text file c:\cps\bin.u\gr_ga.txt as functions of the LOR incidence angles with the face of each crystal. The file contains discretized values: one for every five degrees for the front and back layers respectively.

Geometric profiles

Legend: ■ Front ◆ Back

X-axis: Angle (-80 to 80)
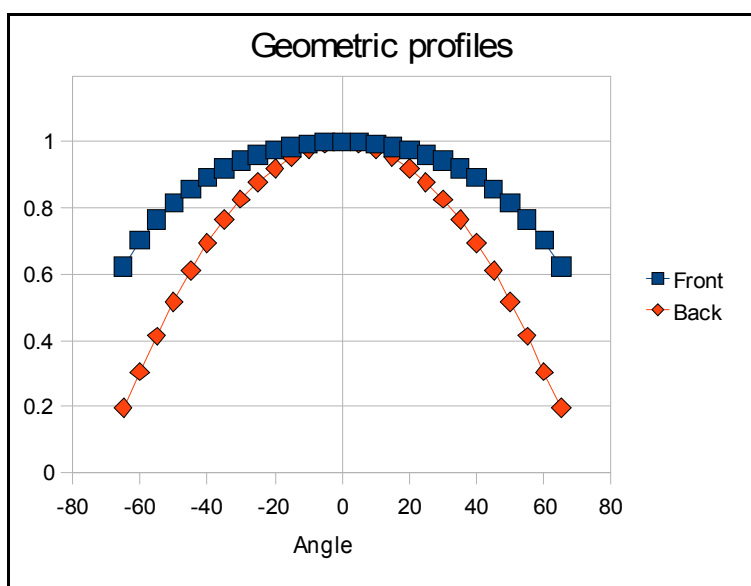
5.3 Functions

norm_process is a command line function. The usage is: norm_process lm_file|ce_file [-o norm_file] [options].

The command prints the usage if no argument is provided. The first argument is the input file (listmode or crystal efficiencies). If the output file name is not specified with -o option, it is derived from the input file name by changing the extension to .n.

Tag	Switch	Description
S5.1	-s span,rd	Specify the span and optionally the maximum ring difference. The defaults are 9 and 67.
S5.2	-d duration	Only process the specified scan duration from the beginning of the listmode data (given in seconds).
S5.3	-L mode	Request low resolution mode (1 or 2). The low resolution mode uses a virtual crystal size twice the size (one gets 4x4 blocks instead of 8x8 blocks). The span and maximum ring difference are 7 and 38. The sinogram bin size is 2mm for mode=1 and 2.4375mm for mode 2. The plane separation is 2.4375mm for both modes.
S5.4	-g geo_fname	Specify radial and axial geometry filename
S5.5	-I max_iter	Set maximum number of iterations (default 30)
S5.6	-M min_rmse	Set minimum RMSE for convergence criteria (default=10e-9)
S5.7	-c corr_bits	Set corrections to be applied when computing fansum: Obliqueness=0x1, RotationDwell=0x2, SolidAngle=0x4, GeomRadial=0x8, GeomAxial=0x10. All corrections are applied by default. Example: -c 7 to exclude geometric

		radial and axial corrections.
S5.8	-K	Use Cologne geometry (default normal)
S5.9	-R r,x0,y0	Set rod rotation radius r and center x0,y0 in mm (default 155,0,0).
S5.10	-T dwell_thr	Set maximum rotation dwell for LOR fansum (default=100).

Table 6: Tags and descriptions of norm_process functions.

6. lmhistogram_u

lmhistogram_u is a modified version of lmhistogram. lmhistogram_u doesn't save the random sinogram since the smoothed randoms used for reconstruction is computed from the coincidence histogram (.ch) file. The true sinogram used for computing the scatter is created in span9 for both span 3 and 9 processing. The scatter is computed in span 9 for both span 3 and 9 reconstructions (see e7_sino_u and hrrt_osem3d).

Modified Functions: No Random Sinogram Output

Tag	Switch	Description
S6.1	-pr	Does not save random sinogram.
S6.2	-span 3	If separate prompts and delayed in span 3 is requested, only the prompt sinogram is created in span3, the true sinogram used to compute scatter (low frequency) is created in span 9.

New Functions: Low Resolution

Tag	Switch	Description
S6.3	-L 1	Low Resolution mode 1: binsize=2mm, plane separation=2.4375mm, span=7, maximum ring difference=38
S6.4	-L 2	Low Resolution mode 2: binsize=2.4375mm, plane separation=2.4375mm, span=7, maximum ring difference=38

7. ReconGUI_u

ReconGUI_u is a modified version to use the new versions (lmhistogram_u, e7_atten_u, e7_fwd_u, e7_sino_u, hrrt_osem3d).

Bug Fix

Auto-scaling for MAP-TR works in ReconGUI_u.

Modified Functions

Tag	Switch	Description
S7.1	N/A	Supports 3D OSEM reconstruction without a cluster using hrrt_osem3d
S7.2	N/A	Static reconstruction jobs are always executed on the file server
S7.3	N/A	Dynamic reconstruction jobs are queued to the cluster if enabled (cluster submit directory not empty).

New Functions

Tag	Keyword in recon.ini	Description
S7.4	Use PSF (0=NO, 1=YES)	New keyword in recon.ini to enable/disable using PSF. Default is disabled. ReconGUI_u has check box showing the status in the reconstruction configuration status. Ex: Use PSF (0=NO, 1=YES) := 1
S7.5	Mu Zoom	New keyword in recon.ini to specify sinogram transaxial and axial rebinning for MAP-TR mu-map reconstruction. Example with axial rebinning: Mu Zoom: = 2,3 Example with no axial rebinning: Mu Zoom: = 2,1
S7.6	TX Scatter Factors	New keyword for transmission scatter correction (see e7_atten in section 10). Ex.: TX Scatter Factors:= -0.1,1.18
S7.7	TX_TV3DReg	Integrate Total Variation 3D Regularization (TV3DReg) as an alternative to MAP-TR segmentation in recon.ini. Example: 1- Head=4,0.0,0.005,0.03,10.,0.096,0.02,0.11,10.,0.03,0.07,0.105;$ 2-Germanium phantom=2,0.000,0.005,0.103,0.005,0.050;$ 3-Water phantom=2,0.000,0.005,0.096,0.050,0.050;$ 4-TX_TV3DReg=0.5,2,3 When TX_TV3DReg is selected, ReconGUI_u calls e7_atten_u without segmentation and calls TX_TV3DReg to apply TV3DReg on the mu-map image created by e7_atten_u.
S7.8	N/A	Add segmentation method (MAP-TR or TX_TV3DReg) to the mu-map image header.
S7.8	N/A	Ignore TX scatter correction when using MAP-TR for backward compatibility.
S7.9	txblr	Get TX/Blank ratio from TX and BL headers and call e7_atten_u with the ratio instead of getting the ratio from sinograms (under the

		bed sinogram bins).
S7.10	LBER	Extract LBER from norm header if present and call e7_sino_u with the value. Ex.: LBER := 12.0

8. Interfile to ECAT Conversion: if2e7

if2e7 2.3.0 is a merge of features from:
–Amsterdam (date manipulations, -q option to remove hot pixels)
–Aarhus to enter patient weight and dosage information (strength and time)
–John Hopkins to enable scanner dependent dead-time

Modified Functions

None

Tag	Switch	Description
S8.0	Backward compatibility	If2e7 should give the same results (with 0.1% difference) that previous version when the same inputs and arguments are used.

Table 6: Tags and descriptions of norm_process functions.

New Functions

Tag	Switch	Description
S8.1	-F name	Set Hospital (Facility) name
S8.2	-D dirname	Specify a secondary storage directory (the ECAT image is copied in a patient sub-directory)
S8.3	-T	Trim empty planes using boundaries extracted from the mu-map
S8.4	-S dirname	Specify calibration files directory. If2e7 searches the directory for calibration files and selects the one with matching scan date.
S8.5	N/A	Use mu-map mask to find image extrema and avoid hot spots

9. Scatter Parameter Adjustment Tool: calcringroiratio

calcringroiratio 1.0.0 is a recompiled version of Roman Krais's original version 0.3.0.

New Functions

None.

Modified Functions

None.

10. e7_atten_u: transmission scatter correction

Modified Functions

None.

Tag	Switch	Description
S10.0	Backward compatibility	E7_atten_u should give the same results (with 0.1% difference) that e7_atten version when the same inputs and arguments are used.

New Functions

Tag	Switch	Description
S10.1	--txsc a,b	Specifiy transmission scatter correction a,b factors: $\ln(ACF) = a + b*\ln(bl/tx)$
		Default: 0,1.0 is equivalent to original method without scatter correction. The scatter is accounted for by scaling the mu-map so that the histogram peak (water peak) is 0.096.
		Recommended values: -0.1,1.18 (see TX-Scatter-correction-21jul08.pdf). When b is not one, an absolute scaling (0.096/0.086) is applied to get mu value at 511KeV from 662KeV.
S10.2	--txblr r	Specify TX/BL ratio instead of getting it from data (under the bed sinogram bins).

11. Calibration:CorrectRun

calcringroiratio 1.0.0 is a recompiled version of Roman Krais's original version 0.3.0.

Bug Fix

CorrectRun applies inter-frame decay and computes correct calibration factors using ^{18}F or ^{11}C.

New Functions

None.

Modified Functions

None.

12. References

1. C. Comtat et al, "Image based resolution modeling for the HRRT OSEM reconstruction software", IEEE MIC conference record, Dresden, 2008