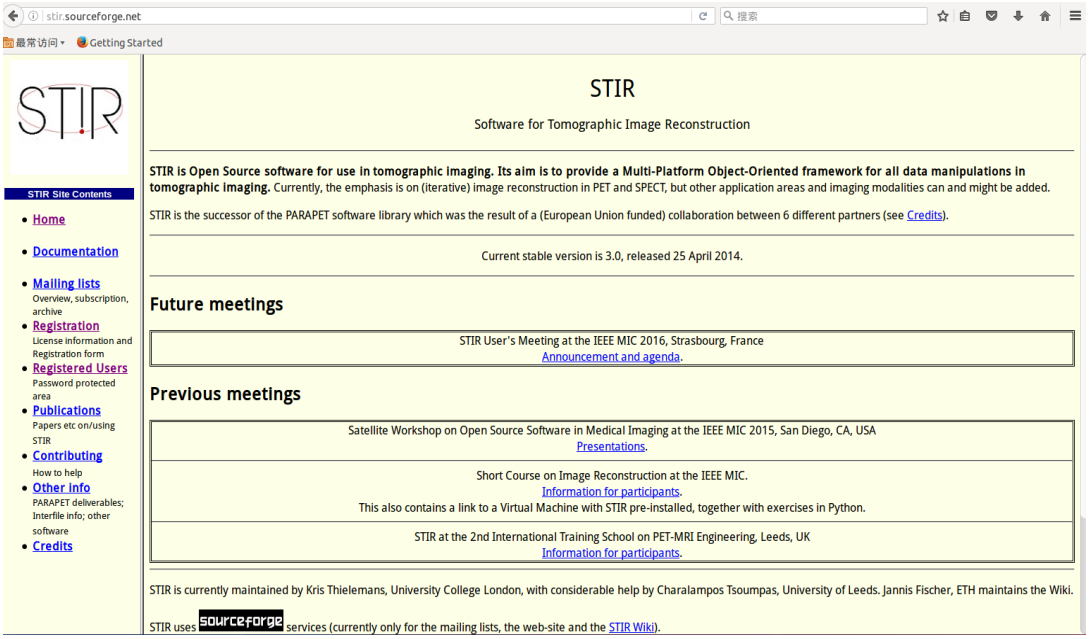
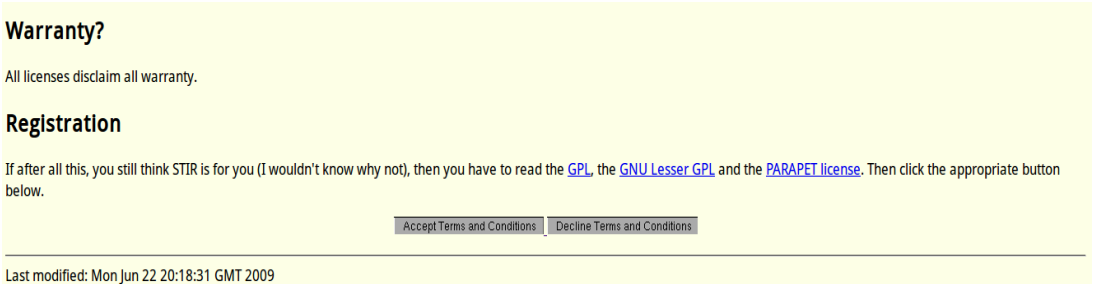
STIR 简介

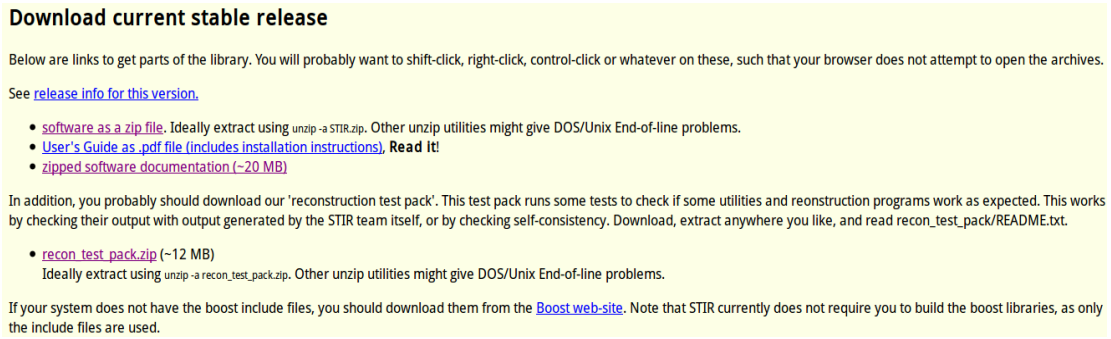
STIR 安装步骤

第一步：注册。进入 STIR 网站，网址：http://stir.sourceforge.net/。点击页面左边的 Registration，在跳转的页面最下方点击 Accept Terms and Conditions,然后按照跳出页面的要求发送邮件进行注册。





第二步：下载安装包。在网页下点击 Registered Users，输入用户名和密码。点击中间区域 software as a zip file 下载安装包，同时点击 recon test pack.zip 下载测试包。



Download current stable release

Below are links to get parts of the library. You will probably want to shift-click, right-click, control-click or whatever on these, such that your browser does not attempt to open the archives.

See release info for this version.

- software as a zip file. Ideally extract using unzip -a STIR.zip. Other unzip utilities might give DOS/Unix End-of-line problems.
- User's Guide as .pdf file (includes installation instructions), **Read it**!
- zipped software documentation (~20 MB)

In addition, you probably should download our 'reconstruction test pack'. This test pack runs some tests to check if some utilities and reonstruction programs work as expected. This works by checking their output with output generated by the STIR team itself, or by checking self-consistency. Download, extract anywhere you like, and read recon_test_pack/README.txt.

- recon_test_pack.zip (~12 MB)
  Ideally extract using unzip -a recon_test_pack.zip. Other unzip utilities might give DOS/Unix End-of-line problems.

If your system does not have the boost include files, you should download them from the Boost web-site. Note that STIR currently does not require you to build the boost libraries, as only the include files are used.

除此之外，还需要 BOOST 安装包。可以在 http://www.boost.org 下载。

ECAT7 安装包。在 http://www.opengatecollaboration.org/ECAT 下载

第三步：安装所有必要文件

创建目录

mkdir /home/twj/stir

把所有安装包放入该目录下

1）安装 ECAT

mkdir ecat7

mv ecat.tar.gz ecat7　　//将压缩包移动到 ecat7 目录下

cd ecat7

tar -zxf ecat.tar.gz　　//解压压缩包

cp Makefile.unix Makefile

make(注 : 不能用 make -jN)

mkdir include

cp *.h include

检查 libecat.a 在 lib 文件夹中 , 如果没有操作以下步骤

mkdir lib

cp libecat.a /lib

配置环境

export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/PATH_TO/ecat7/lib

2) 解压 BOOST

tar -zxf boost_1_61_0.tar.bz2　　//解压压缩包

准备工作完成后，安装 STIR 软件

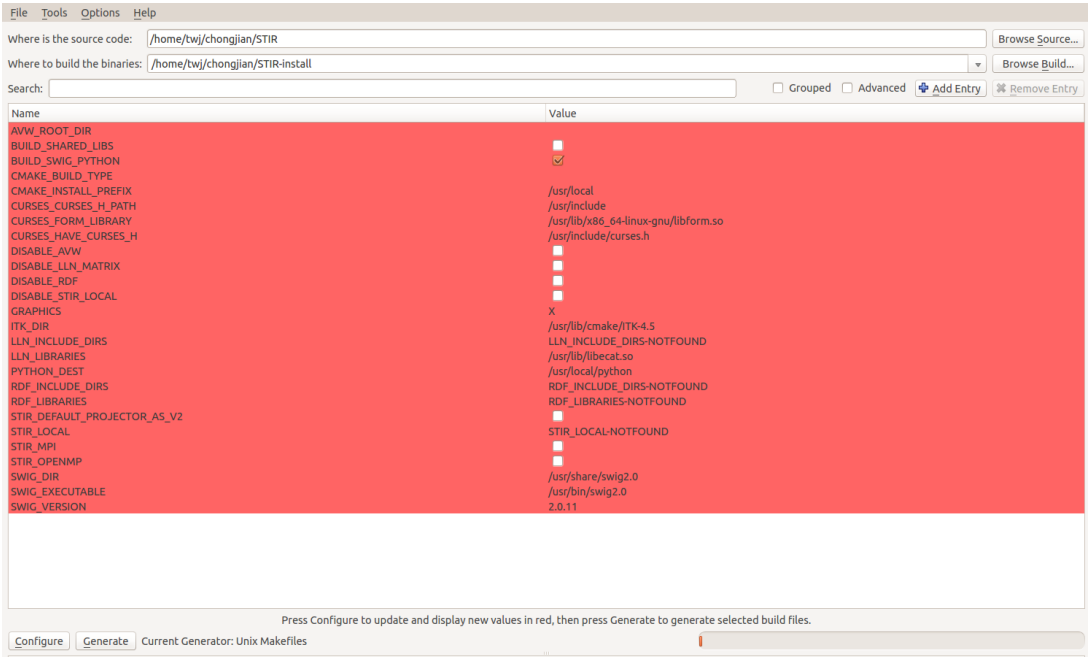
第四步：安装 ST

手动解压 STIR.zip 文件到当前目录下

cd ..

mkdir STIR-install　　//新建一个安装目录

打开 cmake 软件，如图



点击右上角的 Browse Source，选择源文件（安装包）的路径

再点击 Browser Build，选择安装目录

点击左下角 Configure

完成后点击 Generate

其中选项按照上图选择即可。

第五步：测试

解压测试包 recon_test_pack.zip

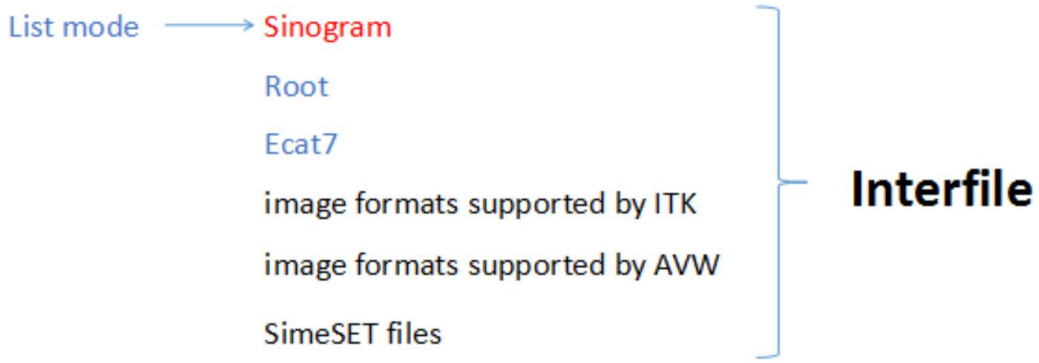
cd recon_test_pack

sh run_tests.sh --nointbp ../STIR-install/bin

如果程序能够正常完成执行即安装成功，否则会报错。

使用步骤

Part1:输入文件



STIR 在能够处理的特定格式的数据文件，该文件格式是 interfile。其他格式文件也能读入，但依然存在各种各样的问题，在实际应用中可以先转换成 interfile，再进行后续处理，如上图所示。其中 list mode、sinogram、root、ecat7 可以由 GATE 运行生成，因此在相对于其他几种格式的文件来说更为常用，而 sinogram 最为常用，这是由于输入的 interfile 与 sinogram 为同一数据。

What is Interfile?

Interfile=Header text file+data file（*.hs+*.s）

Header text file 不仅给出对应的 data file 的数据格式、图像的像素数及层数，还给出了探测器相关结构参数，如下图所示：

```
!INTERFILE :=
name of data file := derenzo3new3.s
originating system := USERDEFINED
!GENERAL DATA :=
!GENERAL IMAGE DATA :=
!type of data := PET
imagedata byte order := LITTLEENDIAN
!PET STUDY (General) :=
!PET data type := Emission
applied corrections := {arc correction}
!number format := float
!number of bytes per pixel := 4
number of dimensions := 4
matrix axis label [4] := segment
!matrix size [4] := 159
matrix axis label [2] := view
!matrix size [2] := 288
matrix axis label [3] := axial coordinate
!matrix size [3] :=
{ 80,79,79,78,78,77,77,76,76,75,75,74,74,73,73,72,72,71,71,70,70,69,69,68,68,67,67,66,66,65,65,64,64,63,
matrix axis label [1] := tangential coordinate
!matrix size [1] := 288
minimum ring difference per segment :=
{ 0,-1,1,-2,2,-3,3,-4,4,-5,5,-6,6,-7,7,-8,8,-9,9,-10,10,-11,11,-12,12,-13,13,-14,14,-15,15,-16,16,-17,17
maximum ring difference per segment :=
{ 0,-1,1,-2,2,-3,3,-4,4,-5,5,-6,6,-7,7,-8,8,-9,9,-10,10,-11,11,-12,12,-13,13,-14,14,-15,15,-16,16,-17,17
```

其中，name of data file 为输入数据名称

imagedata byte order 取决于 PC（一般是 little Endian）

number format 为数据存储类型，取 float

number of bytes per pixel 取 4

number of dimensions 为 4

matrix size[1]和 matrix size[2]是用来定义一条 LOR 的位置，分别定义它的距离和角度，其中角度对应实际角度中的 0-180 度。

matrix size[4]为数据分类，取环数 2 倍减 1,如 32 环的数据则对应 63 个 segment

matrix size[3]为轴向坐标，与 matrix size[4]相关，表示每个 segment 的数据层数

minimum ring difference per segment 和 maximum ring difference per segment 为两个数组，数组中的值一一对应，也与 matrix segment[2]也必须一一对应，一般设置为{0，-1，1，……，-（最大环数差）+1，最大环数差-1，-（最大环数差），最大环数差}。

举个例子：如某一个 5 环的探测器，其 oblique sinogram 有 25 层，这 25 层按照环差可以分为 9 类，即为上述 segment 数量，分别对应环差为 0,-1,1,-2,2,-3,3,-4,4，即为上述 minmum ring difference 和 maximum ring difference，环差为 0 时有 5 层数据，环差为-1 和 1 时有 4 层数据，环差为-2 和 2 时有 3 层数据，环差为-3 和 3 时有 2 层数据，环差为-4 和 4 时有 1 层数据，即为上述 axial coordinate。

```
Scanner parameters:=
Scanner type := USERDEFINED
Number of rings                             := 80
Number of detectors per ring                := 576
Inner ring diameter (cm)                    := 34
Average depth of interaction (cm)           := 0.7
Distance between rings (cm)                 := 0.25
Default bin size (cm)                       := 0.118
View offset (degrees)                       := 0
Maximum number of non-arc-corrected bins := 288
Default number of arc-corrected bins     := 288
Number of blocks per bucket in transaxial direction         := 1
Number of blocks per bucket in axial direction              := 1
Number of crystals per block in axial direction             := 32
Number of crystals per block in transaxial direction        := 8
Number of detector layers                                   := 1
Number of crystals per singles unit in axial direction      := 32
Number of crystals per singles unit in transaxial direction := 8
end scanner parameters:=
effective central bin size (cm) := 0.118
number of time frames := 1
!END OF INTERFILE :=
```

该部分为环形探测器的结构参数，包括层数、每层晶体数量，环的内直径，环间距（轴向长度/层数）。除此以外，average depth of interaction 取 0.5-0.7 都可以

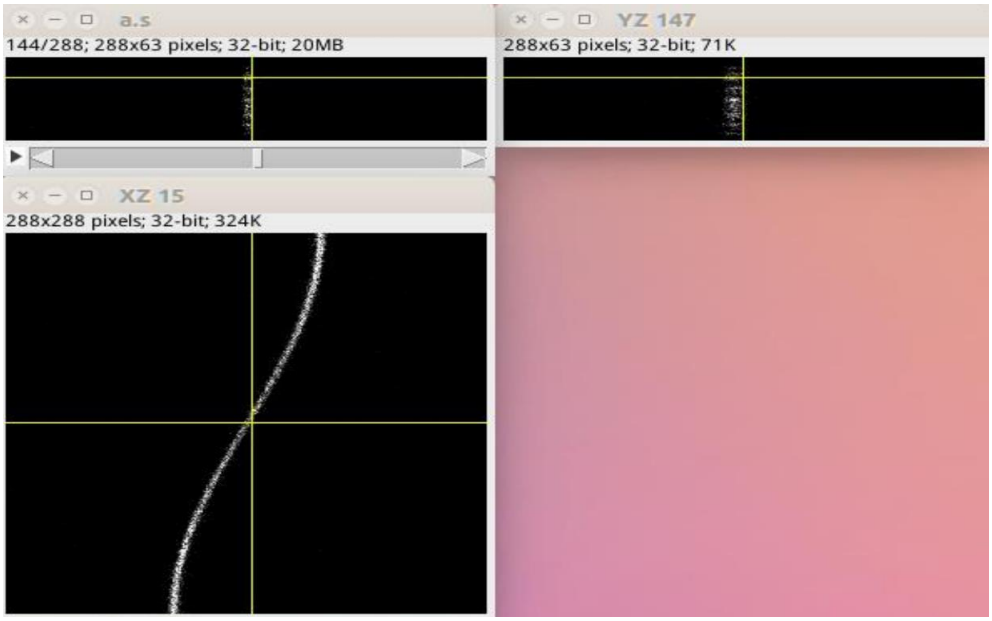
bin size 和 effective central bin size 取（内直径/bin 个数）

view offset 取 0

maximum number of non-arc-corrected bins 和 default number of arc-corrected bins 取 tangential coordinate

number of time frames 取 1。

data file 文件按如图所示:



该文件数据内容与单层重排后的 sinogram 一致，其中左上图 interfile 内容，左下图即为 sinogram 数据。

Part2:重建算法

OSMAPOL

该程序执行 IF-OSEM-OSL 算法。类似于 OSEM 算法，但功能多于 OSEM。它能够实现以下功能：

use of subsets　子集大小必须近似相等

inter-update filtering　原始图像更新之前进行滤波

inter-iteration filtering　迭代过程中（即完成某次图像更新后进行滤波）进行滤波

post-filtering　最后一次迭代后进行滤波

prior information

random order of the subsets in each iteration

```
OSMAPOSLParameters :=
;lines starting with semicolons are comments
objective function type:= \
PoissonLogLikelihoodWithLinearModelForMeanAndProjData
PoissonLogLikelihoodWithLinearModelForMeanAndProjData Parameters:=
; input, sensitivity and prior parameters here
```

```
input file := projection_data_filename.hs     %输入数据头文件名
; use -1 to use the maximum available
; maximum absolute segment number to process := 4   %迭代中使用的层数，一般定义为-1 为使用全部层数
; zero end planes of segment 0 := 1
; keywords that specify the projectors to be used
Projector pair type := Matrix
Projector Pair Using Matrix Parameters :=
; Use the PET Ray-tracing matrix.
; This needs to be changed to SPECT UB when using SPECT data
Matrix type := Ray Tracing
Ray Tracing Matrix Parameters:=
End Ray Tracing Matrix Parameters:=
End Projector Pair Using Matrix Parameters :=       %投影数据相关定义
; background (e.g. randoms)
additive sinogram := 0                    %是否有随机事件、散射事件等，若有可在此处添加相关头文件
; sensitivity related keywords
; time frame info used for dead-time calculation when using ECAT7
;time frame definition filename:=
;time frame number:= 1
; normalisation and attenuation info
; Bin Normalisation type:= None

recompute sensitivity := 1
use subset sensitivities:=1 ; recommended
; optional filename to store/read the sensitivity image
; (if use subset sensitivity is off)
; sensitivity filename:=
; optional filename to store/read the subsensitivities
; use %d where you want the subset-number (a la printf)
subset sensitivity filenames:= sens_%d.hv              %对不同子集采用不同的灵敏度定义，相应定义从文件中读取
; keywords for specifying the prior information
prior type := None                        %提供先验信息
; next keywords can be used to specify image size, but will be removed
; they are ignored when using an initial image
zoom := 1
; use --1 for default sizes that cover the whole field of view
XY output image size (in pixels) := -1
end PoissonLogLikelihoodWithLinearModelForMeanAndProjData Parameters:=
; set output file format, if omitted a default value will be used
Output file format := Interfile
Interfile Output File Format Parameters :=
; byte order := little-endian
; number format := signed integer
; number of bytes per pixel := 2
End Interfile Output File Format Parameters :=
initial estimate:= initial_image_filename.hv
enforce initial positivity condition:=1
number of subsets:= 6
start at subset:= 0
number of subiterations:= 30
start at subiteration number:=1
output filename prefix := out_file
save estimates at subiteration intervals:= 2
uniformly randomise subset order:= 1          %输出文件的格式及参数，定义了子集及迭代次数
; keywords that specify the filtering that occurs after every subiteration
; warning: do not normally use together with a prior
inter-iteration filter subiteration interval := 4
inter-iteration filter type := Separable Cartesian Metz
; keywords below will depend on the filter type (see text)
separable cartesian metz filter parameters :=
x-dir filter fwhm (in mm) := 6
y-dir filter fwhm (in mm) := 6
```

```
z-dir filter fwhm (in mm) := 6
; use some sharpening here as example (not really recommended though)
x-dir filter metz power := 2
y-dir filter metz power := 2
z-dir filter metz power := 2
end separable cartesian metz filter parameters :=
; keywords that specify the filtering that occurs at the end
; of the reconstruction
post-filter type := None
; keywords that specify the filtering that occurs before
; multiplying with the update image
inter-update filter subiteration interval := 4
; would have to be filled in.
inter-update filter type := None
map model := additive                    %定义是否使用滤波器以及所使用滤波器的参数（取决于滤波器的类型）
; keywords for preventing too drastic (multiplicative) updates
; below just set to their default values
maximum relative change := 3.40282e+38
minimum relative change := 0              %乘法更新阈值
; enabling this will write the multiplicative update images
; every sub-iteration
write update image := 0
END :=
```

以上各参数中加红部分为最基本参数设置，必须定义完整。其余参数可根据实际情况加入。

OSSPS

该程序执行有序子集的梯度下降算法。

$$\lambda^{\text{new}} = \lambda + \zeta D \nabla \Psi$$

其中 λ 为待评估值，Ψ 为目标函数，D 为预处理器（取决于 Ψ），ζ 为松弛参数。由 $\zeta = \frac{\alpha}{1+\gamma n}$ 可对 ζ 进行设置，n 为迭代次数除以子集数。

```
OSSPSParameters :=

; sample file for OSSPS

; parameters used here are for illustrative purposes only

; i.e. they are not recommended values


; Note:

; some variables here are indicated with ${VAR}

; These can be initialised as environment variables before

; running POSSPS. E.g. in bash you could do

;    MAXSEG=2 NUMSUBS=6 other_variables_here POSSPS POSSPS.par

; Alternatively, copy this file and edit it obviously.


objective function type:=PoissonLogLikelihoodWithLinearKineticModelAndDynamicProjectionData
```

```
PoissonLogLikelihoodWithLinearKineticModelAndDynamicProjectionData Parameters:=

input file := fwd_dyn_from_p0005-p5.S

; if next disabled, defaults to maximum segment number in the file
maximum absolute segment number to process := ${MAXSEG}

projector pair type := Matrix
  Projector Pair Using Matrix Parameters :=
  Matrix type := Ray Tracing
  Ray tracing matrix parameters :=
  End Ray tracing matrix parameters :=
End Projector Pair Using Matrix Parameters :=

; if the next parameter is disabled,
; the sensitivity will be computed using the normalisation object
sensitivity filename:= sens_POSSPS.img
; if next is set to 1, sensitivity will be recomputed
; and written to file (if "sensitivity filename" is set)
recompute sensitivity := 1
; background term (i.e. randoms and scatter)
additive sinograms := 0

; see STIR doc:  use 1 if segment 0 has only ring difference 0
; zero_segment 0_end_planes:= 0
 zero end planes of segment 0:= 0

;prior type:= Quadratic
;quadratic prior parameters :=
;penalisation factor := .5
;only 2D:=1
;kappa filename := kappas_a_la_fessler.hv
;end quadratic prior parameters:=

; patlak related files
Kinetic Model type := Patlak Plot
Patlak Plot Parameters :=
time frame definition filename := time.fdef
starting frame := 23
```

calibration factor := 9432.31

blood data filename := plasma.if

Time Shift := 0

In total counts := 1

;In correct scale := 0

end Patlak Plot Parameters :=

end PoissonLogLikelihoodWithLinearKineticModelAndDynamicProjectionData Parameters:=

output filename prefix:=POSSPS

; iteration scheme

; Number of subsets should be a divisor of num_views/4

number of subsets:=${NUMSUBS}

; Use for starting the numbering from something else than 1

start at subiteration number:=1

; Use if you want to start from another subset than 0 (but why?)

start at subset:= 0

number of subiterations:= ${ITER}

save estimates at subiteration intervals:= ${SAVITER}

;write update estimate := 0

; if next is disabled, defaults to image full of 1s (but that's not good for OSSPS)

; in particular, make sure it has the correct scale

initial estimate := indirect_Patlak.img

enforce initial positivity condition := 1

; additional regularisation

;inter-iteration filter subiteration interval:= 0

;inter-iteration filter type := none

; here start OSSPS specific values

; values to use for the 'precomputed denominator'

  ; if you do not specify the following keyword, the 'precomputed denominator'

  ; will be computed automatically (and saved)

  ; use the following if you have it already (e.g. from previous run)

  ; note: setting the value to 1 will use an images full of ones (which is not a good idea!)

  ; precomputed denominator := my_precomputed_denominator.hv

; specify relaxation scheme

; lambda = relaxation_parameter/ (1+relaxation_gamma*(subiteration_num/num_subsets)

relaxation parameter := 1

relaxation gamma:=.1 %借助上述公式对 ζ 进行设置

END :=

FBP2D

该程序执行 single slice rebinning 和 FBP 算法。

```
fbp2dparameters :=
input file := input.hs
output filename prefix := output
; output image parameters
; zoom defaults to 1
zoom := 1
; image size defaults to whole FOV
xy output image size (in pixels) := 180
; can be used to call SSRB first
; default means:
; if no axial compression, use 3
; otherwise, use 1
;num segments to combine with ssrb := -1        %可以设置是否使用 SSRB

; filter parameters, default to pure ramp
alpha parameter for ramp filter := 1
cut-off for ramp filter (in cycles) := 0.5        %滤波器使用海明窗，此处根据公式(α + (1 − α) ∗ cos(π ∗ f/fc))对 α 和 f 进行设置

; keywords that specify the filtering that occurs at the end
; of the reconstruction
post-filter type := None
end :=
```

该过程中使用到的 SSRB 算法的设置，最完整的参数包括输入输出文件名、结合层数数量（必须是奇数）或者结合的视图数量、标准化（可选）、最大待处理层数（默认为总层数）

FBP3DRP

与 FBP2D 基本类似，默认使用的滤波器是“pure”Colsher filter。

Part3:输出文件

Herder text file+data file(*.hv+*.v)

Header 文件中包含了对应的数据文件名、数据格式、图像像素及层数等信息。

```
!INTERFILE  :=

name of data file := true1r.v

!GENERAL DATA :=
```

```
!GENERAL IMAGE DATA :=
!type of data := PET
imagedata byte order := LITTLEENDIAN
!PET STUDY (General) :=
!PET data type := Image
process status := Reconstructed
!number format := float
!number of bytes per pixel := 4
number of dimensions := 3
matrix axis label [1] := x
!matrix size [1] := 91
scaling factor (mm/pixel) [1] := 8.8
matrix axis label [2] := y
!matrix size [2] := 91
scaling factor (mm/pixel) [2] := 8.8
matrix axis label [3] := z
!matrix size [3] := 63
scaling factor (mm/pixel) [3] := 2.2
first pixel offset (mm) [1] := -396
first pixel offset (mm) [2] := -396
first pixel offset (mm) [3] := 0
number of time frames := 1
!END OF INTERFILE :=
```

Part4:三维重建应用实例

本示例中完成从 GATE 仿真结果的 root 和 sinogram 数据到 interfile 数据的转换，并分别利用 STIR 中的 FBP3DRP 和 OSEM 完成重建。

分别利用 FBP 和 OSEM 算法对图像进行重建，ECAT 系统探测器及 phantom 参数如下：

探测内半径 41.2cm，32 环，轴向长度 15.52cm，72 个模块，每个模块 64 个晶体，晶体大小是 30mm×4.4mm×4.75mm，phantom 为 derenzo 模型，该模型只有一层，厚度为 6mm，每层 512×512 个像素，每个像素 0.6mm×0.6mm，因此整个 phantom 直径 30cm 左右，其中最小点 7.2mm。

头文件中参数设置如下：

!INTERFILE :=

name of data file := ceshi72.s

originating system := USERDEFINED

!GENERAL DATA :=

!GENERAL IMAGE DATA :=

!type of data := PET

imagedata byte order := LITTLEENDIAN

!PET STUDY (General) :=

!PET data type := Emission

applied corrections := {arc correction}

!number format := float

!number of bytes per pixel := 4

number of dimensions := 4

matrix axis label [4] := segment

!matrix size [4] := 63

matrix axis label [2] := view

!matrix size [2] := 288

matrix axis label [3] := axial coordinate

!matrix size [3] :=
{ 32,31,31,30,30,29,29,28,28,27,27,26,26,25,25,24,24,23,23,22,22,21,21,20,20,19,19,18,18,17,17
,16,16,15,15,14,14,13,13,12,12,11,11,10,10,9,9,8,8,7,7,6,6,5,5,4,4,3,3,2,2,1,1 }

matrix axis label [1] := tangential coordinate

!matrix size [1] := 288

minimum ring difference per segment := { 0,-1,1,-2,2,-3,3,-4,4,-5,5,-6,6,-7,7,-8,8,-9,9,-10,10,-
11,11,-12,12,-13,13,-14,14,-15,15,-16,16,-17,17,-18,18,-19,19,-20,20,-21,21,-22,22,-23,23,-
24,24,-25,25,-26,26,-27,27,-28,28,-29,29,-30,30,-31,31 }

maximum ring difference per segment := { 0,-1,1,-2,2,-3,3,-4,4,-5,5,-6,6,-7,7,-8,8,-9,9,-10,10,-
11,11,-12,12,-13,13,-14,14,-15,15,-16,16,-17,17,-18,18,-19,19,-20,20,-21,21,-22,22,-23,23,-
24,24,-25,25,-26,26,-27,27,-28,28,-29,29,-30,30,-31,31 }

Scanner parameters:=

Scanner type := USERDEFINED

Number of rings := 32

Number of detectors per ring := 576

Inner ring diameter (cm) := 82.4

Average depth of interaction (cm) := 0.7

Distance between rings (cm) := 0.485

Default bin size (cm) := 0.286

View offset (degrees) := 0

Maximum number of non-arc-corrected bins := 288

Default number of arc-corrected bins := 288

Number of blocks per bucket in transaxial direction := 1

Number of blocks per bucket in axial direction := 1

Number of crystals per block in axial direction := 32

Number of crystals per block in transaxial direction := 8

Number of detector layers := 1

Number of crystals per singles unit in axial direction := 32

Number of crystals per singles unit in transaxial direction := 8

end scanner parameters:=

effective central bin size (cm) := 0.286

number of time frames := 1

!END OF INTERFILE :=

OSEM 参数设置如下：

OSMAPOSLParameters :=

objective function type:= PoissonLogLikelihoodWithLinearModelForMeanAndProjData

PoissonLogLikelihoodWithLinearModelForMeanAndProjData Parameters:=

input file := your3d.hs

;zero end planes of segment 0:= 0 ; segment 0 is has direct and indirect planes

; if disabled, defaults to maximum segment number in the file

;maximum absolute segment number to process := -1

projector pair type := Matrix

Projector Pair Using Matrix Parameters :=

Matrix type := Ray Tracing

```
  Ray tracing matrix parameters :=
   number of rays in tangential direction to trace for each bin := 10
   do symmetry 90degrees min phi := 1
   do symmetry 180degrees min phi := 1
  End Ray tracing matrix parameters :=
  End Projector Pair Using Matrix Parameters :=
 ; Bin Normalisation type := from projdata
   ; Bin Normalisation From ProjData :=
   ; normalisation projdata filename:= ${MULTFACTORS}
   ; End Bin Normalisation From ProjData:=
;additive sinogram := ${ADDSINO}
xy output image size (in pixels) := 180
zoom := 1
use subset sensitivities:=1
;subset sensitivity filenames:= my_DSTE_sens_2D_PM_s14_%d.hv
recompute_sensitivity:=1
prior type := quadratic
   Quadratic Prior Parameters:=
   penalisation factor := 0
   ;weights:={{{0,1,0},{1,0,1},{0,1,0}}}
  END Quadratic Prior Parameters:=
end PoissonLogLikelihoodWithLinearModelForMeanAndProjData Parameters:=
output filename prefix := derenzo3new3
number of subsets:= 8
start at subset:= 0
number of subiterations:= 8
save estimates at subiteration intervals:=8
;report objective function values interval := 1
END :=
```

FBP3D 参数设置如下：

fbp3drpparameters :=

input file := your3d.hs

output filename prefix := ceshi72

; all following parameters are optional

;;;;;;; output image parameters

zoom := 1

; defaults to cover whole FOV

xy output image size (in pixels) := 180

;maximum absolute segment number to process := 63

;;;;;;; parameters for initial image

; you can use an existing image (but be careful about the scale!)

; image to be used for reprojection := some_image

; or you can use FBP on 2D data. following are reconstruction parameters for 2D

; default means: call SSRB only if no axial compression is already present

num segments to combine with ssrb := 1

; filter parameters, default to pure ramp

alpha parameter for ramp filter := 1

cut-off for ramp filter (in cycles) := 0.5

;;;;;;;; parameters for Colsher filter

alpha parameter for colsher filter in axial direction := 1

cut-off for colsher filter in axial direction (in cycles) := 0.5

alpha parameter for colsher filter in planar direction := 1

cut-off for colsher filter in planar direction (in cycles) := 0.5

; define colsher on finer grid. The higher the number, the better (but slower)

stretch factor for colsher filter definition in axial direction := 2

stretch factor for colsher filter definition in planar direction := 2

; allow less padding. DO NOT USE

transaxial extension for fft := 1

axial extension for fft := 1

;;;;;;;;; other parameters

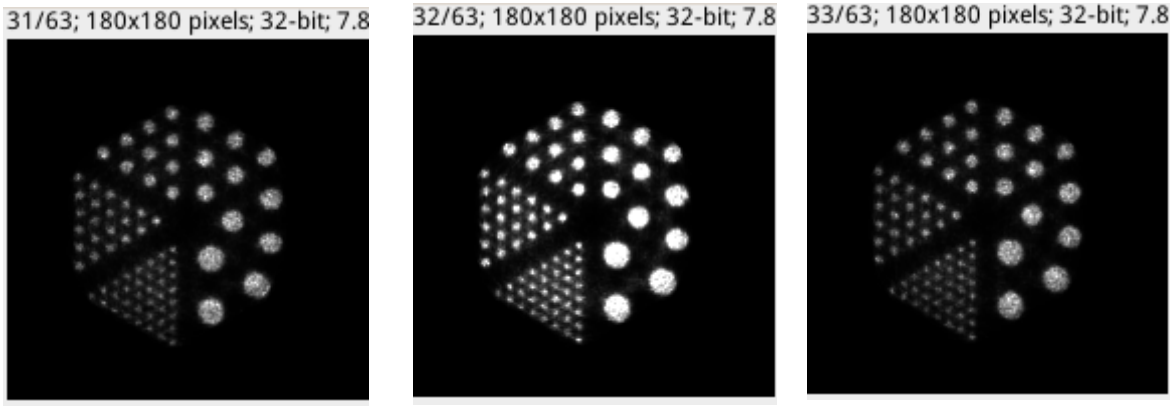
save intermediate images := 0

display level := 0

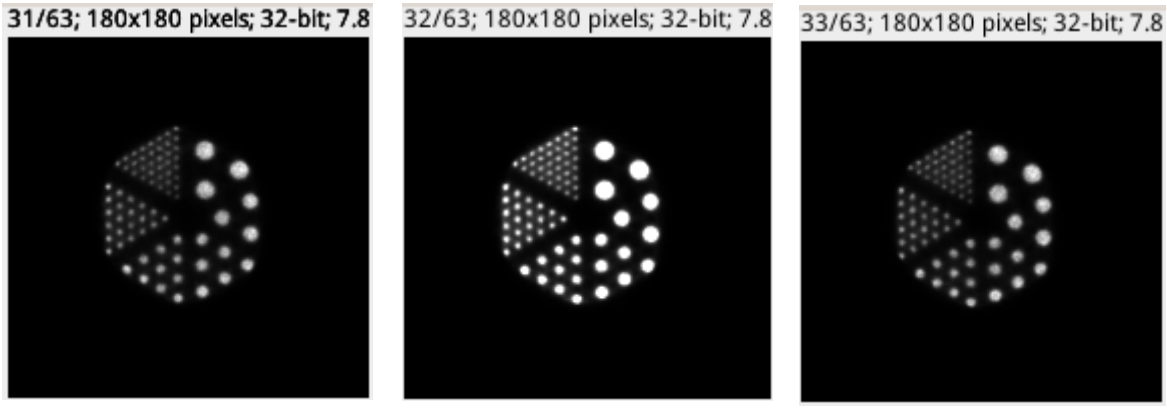
end :=

重建结果如下：

sinogram 数据的迭代重建结果（空间中的三层）



root 数据的迭代重建结果



FBP3DRP 重建结果