Glossary for STIR

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Version 6.2

Originally based on PARAPET Deliverable 4.1, Extended for Quantitative Reconstruction and motion compensation

Introduction

The purpose of this document is to define the terms used by STIR, as not everyone in the nuclear medicine community uses the same words. In addition, it also gives a brief overview and explanation of data concepts. However, this is all kept brief. Please read additional material, for instance [Fah2002].

Most of specifics of this document related to PET scanners, but a lot of terminology has clear correspondence for SPECT. However, most SPECT scanners rotate one or more gamma cameras around the patient, as opposed to have a ring of detectors.

Basics

Geometry A cylindrical geometry has been chosen to describe positron tomographs made of a number of adjacent detector rings and reconstructed image volumes. The geometry supports consequently two principal directions *axially* along the scanner cylinder and *transaxially* perpendicular to the cylinder axis.

Scanner Geometrically associated to the cylindrical volume defined by the inner dimensions of the positron tomograph.

Detector ring Geometrically associated to the cylindrical volume defined by the dimensions of a detector ring. Note that because currently Depth of Interaction is not taken into account, the effective ring radius used in the building blocks is the sum of the inner ring radius and an average depth of interaction (e.g. $\sim$ 1cm for BGO).

Detector Sometimes called **detector crystal**. Geometrically associated to the inner face of a detector element. The **scanner** is then considered as a tessellation of **detectors** constructing adjacent **rings**. For many scanners, detectors are organized in a block. For instance, on the HR+ scanner, a detector block consists of 8x8 detectors. Current scanners have mini-blocks, related to the read-out. Blocks are often organised in **modules**, currently called **buckets** in STIR.

Time of Flight (TOF) for PET Many modern PET scanners measure the difference in arrival time of the 2 gamma photons with a certain **TOF timing resolution** (often expressed in ps). In current scanners, the TOF information is discretised into **TOF bins**.

LOR (Line-Of-Response) Line joining the centres of two **detectors**. Ignoring scatter, attenuation and other physical effects, the average number of coincidences observed between two detectors can be estimated as the line integral of the tracer distribution along the **LOR**. This does not take the finite width of the **TOR** into account, nor scatter within the detectors. It can be shown that this line integral approximation works best for LORs that do not run parallel to edges within the object. We say that the projector that uses this model is a **ray tracing** projector.

TOR (Tube of response) Tube joining two **detectors**.

Sinogram Set of **bins** corresponding to 1 **segment** and 1 **axial** position and (in STIR) 1 TOF bin. Before **axial compression,** this corresponds to LORs in a **detector ring** (*direct sinogram*) or between two different **detector rings** (*oblique sinogram*). For a **scanner** of n **detector rings**, there are n **direct sinograms** and $n^2 - 1$ **oblique sinograms** for a total of n^2 **sinograms**. With **axial compression**, the number of **direct sinograms** is $2n - 1$. Conventionally, the **view** angle in an oblique sinogram runs only over 180 degrees, meaning that only half of the detectors in each ring are covered[1]. The other half corresponds to the **sinogram** in the opposite **segment** (with minus the average ring difference).

In PET, the number of tangential positions determines the "fan-size". Its maximum is equal to the number of detectors per ring. Scanners use far less you dont want to look at coincidences between neighbouring crystals!).

View The azimuthal angle of an **LOR** (ignoring **interleaving**, see the documentation of the `ProjDataInfoCylindricalNoArcCorr` class). The maximum number of views is half the number of detectors per ring (this is again due to interleaving).

Bin A single element in a sinogram, completely specified by its **segment, axial position, view**, **tangential position** and (in PET) **TOF bin**.

Ring difference (in PET) Number of **rings** between two **rings** associated to a **sinogram**. If *ringA* and *ringB* are the ring numbers, the **ring difference** is given by $ringB - ringA$. Thus there can be *positive* and *negative* **ring differences**.
The (average) **ring difference** of a **direct sinogram** is zero.

Michelogram Representation of **sinograms** on a square grid as shown in Annex 1. If *ringA* and *ringB* are the ring numbers associated to a **sinogram**,

[1] In SPECT, rotations often cover 360 degrees.

ringA is represented on the horizontal axis and *ringB* on the vertical axis. **Positive ring differences** are below the line representing **direct sinograms** and **negative ring differences** above this line.

Segment Set of **merged sinograms** with a common average **ring difference** as shown in Annex 1.

Viewgram Set of equal azimuth **merged LORs** of a **segment**.

Projection data The set of all (measured) LORs, normally split into **segments** etc. The word "projection" is used because after various corrections and ignoring noise, the measured data can be approximated as line integrals through the object.

FOV (Field-Of-View) Geometrically associated to the volume for which there is at least 1 **bin** with non-zero detection probability**.** In many cases, the term is also used for the smaller volume for which there is at least 1 **bin** with non-zero detection probability for every **view**. The latter FOV is usually cylindrical.

Image slice Geometrically associated to a cylindrical volume defined by a slice of the **FOV**. By convention, a **slice** is half the width of a **ring**. For a **scanner** of n **detector rings**, there are $2n$–1 **image slices**.

Direct plane **Image slice** centered on a **ring**. For a **scanner** of n **detector rings**, there are n **direct planes**. The **FOV** is ended by two **direct planes** centered on the first and last **rings**.

Cross plane **Image slice** in between two consecutive **direct planes**. **Direct planes** are adjacent to **cross planes**. For a **scanner** of n **detector rings**, there are $2n$–1 **cross planes**.

Different (lossy) data compressions used

Trimming Reduction of the number of **bins** in tangential direction without changing the size of **bins**. **Trimming** is a type of **bin** truncation.

Angular compression (view mashing) Reduction of the number of **views** by a multiple of two. As an example, doing a **mashing** of 2 means that pairs of **views** have been added 2 by 2 to form only one **view**.

Axial compression (Span), PET Reduction of the number of **sinograms** at different **ring differences** as shown in Annex 1. **Span** is a number used by Siemens/CTI to say how much axial compression has been used. Higher span, more axial compression. Span 1 means no axial compression. See the Annex for more information. Siemens/CTI always uses odd span. Note that GE scanners uses mixed data, where segment 0 has span 3, while other segments have span 2. In **STIR**, we call this *span 2*. As a generalisation, **STIR** supports any even span (where segment 0 has effective span + 1). Finally, for historical reasons **STIR** also support a different mixed format where segment 0 has span 3 but higher segments have span 1, or indeed any mix "spans-per-segment".

SSRB Originally, single slice rebinning was developed to collapse 3D PET data into non-oblique sinograms. In STIR, it is generalised to combine segments, optionally keeping some oblique segments. this effectively increases the **span**.

TOF mashing (PET) Reduction of the number of **TOF bins** by combining adjacent bins. The **TOF mashing factor** is defined as the ratio of the **Maximum number of (unmashed) TOF time bins** supported by the scanner (in list-mode) over the actual number of TOF bins. Currently in STIR, this ratio has to be an integer. The size of a TOF bin is computed by multiplying the **TOF mashing factor** with the **size of unmashed TOF time bins**, with the latter defined as a scanner property. `SSRB` can be used to increase the TOF mashing factor.
Note that many PET scanners use a **TOF mashing factor** greater than 1 for their standard histogrammed projection data.

Terms used in quantitative PET reconstruction

Scatter Point Coordinate where a scatter event takes place.

SSS - Single scatter simulation Estimation of the probability to measure a coincidence event that one of the two photons has been scattered only once.

B-Splines Basis splines are a set of polynomial functions that have minimal support with respect to a given degree, smoothness, and domain partition. In imaging they are useful for performing very fast multidimensional interpolation calculations.

Inverse-SSRB It is the pseudo-inverse operation of single slice rebinning which can be used as the simplest way to extrapolate direct sinograms into indirect sinograms.

Plasma Data Radioactivity concentration in plasma (and blood) during the scanning acquisition. Usually it is measured in kBq/cm^3 over a time window of 1 second.

Dynamic Data/Images A stack of projection data or images through time.

Kinetic Model The kinetic model describe the tracer exchange between plasma and tissue and between tissue compartments.

Kinetic Parameters The parameters of the kinetic model which are estimated such that the model is in agreement with the acquired data.

(Kinetic) Model Matrix Linear kinetic models can be written with compact matrix operations, which relate the dynamic images and the kinetic parameters with the kinetic model matrix. This matrix can be seen as the application of the transformation from parametric domain to the temporal domain.

Patlak Plot For irreversible tracers, after a certain period from tracer injection, the free tracer in tissue reaches equilibrium with the radiotracer in plasma and then the original model simplifies to a linear plot known as the Patlak Plot.

Parametric Image An image whose voxels hold the values the kinetic parameters.

Parametric Image Reconstruction (PIR) Estimation of the kinetic parameters from dynamic images for each voxel (indirect PIR). The parametric images can also be reconstructed directly from dynamic projection data.

Terms used in motion-compensated reconstruction

Gated Data/Images PET acquisitions can be gated according to an external signal (e.g. respiration, ECG). Gated projection data or gated images correspond to one cardiac/respiratory position of the cardiac/respiratory cycle.

Motion Vectors 3D vectors that store the information of the location where the activity was originally. Information is stored in x-y-z motion vectors and they relate the image at the reference position with the image at the corresponding gate.

Motion Compensated Image Reconstruction (MCIR) Incorporates motion information within reconstruction so that a motion-free image is directly reconstructed.

Reconstruct-Transform-Average (RTA) Incorporates motion information after reconstruction to obtain a motion-free image.

ANNEX 1 :Michelogram

Figure 1 shows the michelogram of data for the ART scanner with a maximum **ring difference** of 17 and a **span** of 7.
Segment 0 is on the diagonal.
Each dot would correspond to a single sinogram if no axial compression would be used. Axial compression consists in adding sinograms together whose central LORs intersect the scanner axis in the same point. This can be seen as a generalization of the Single Slice Rebinning Algorithm (**STIR**'s **SSRB** supports any span). In the drawing below, the diagonal lines connecting the dots indicate the sinograms that are added together. The illustration is for **span** 7=4+3 (this terminology was introduced because for some axial positions, 4 sinograms are added, while for others only 3. Note that for even **span**, segment 0 has one more set of axial positions added than the oblique ones.).

References

[Fah2002] FH Fahey, "Data Acquisition in PET Imaging", J Nucl Med Technol 2002; 30:39, 49.
[Fah2004] FH Fahey, 2004 SNM Mid-Winter Educational Symposium slides, online at `http://interactive.snm.org/docs/Fahey%20presentation.pdf`

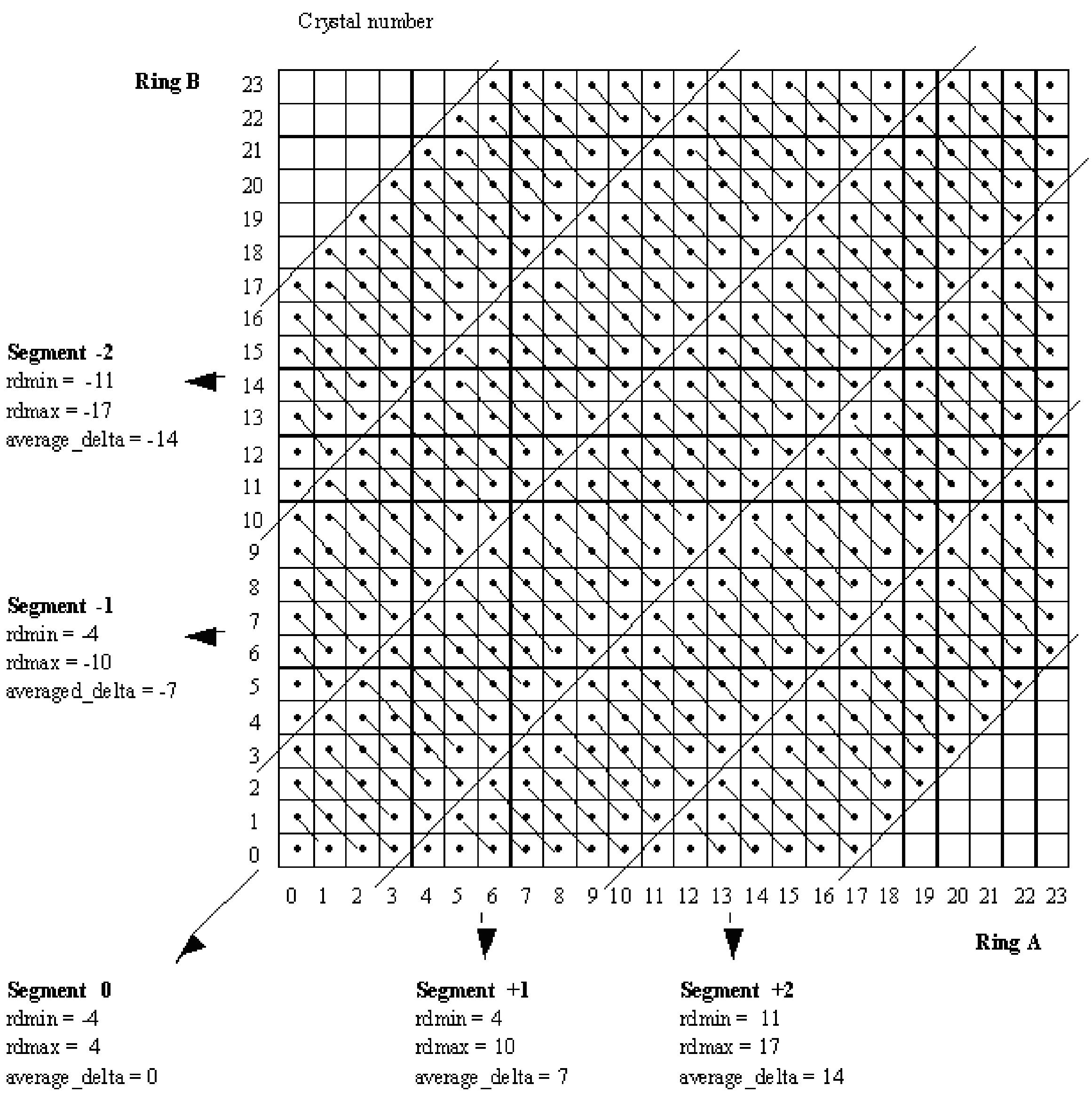

Figure 1: Michelogram with span=7. **Warning**: due to historical reasons, the axis labels are wrong. The horizontal axis corresponds to *ringB*.
Legend:

rdmin the minimum ring difference

rdmax the maximum ring difference

average_delta the averaged ring difference. This is equal to segment_num*span if the span is the same for each segment.

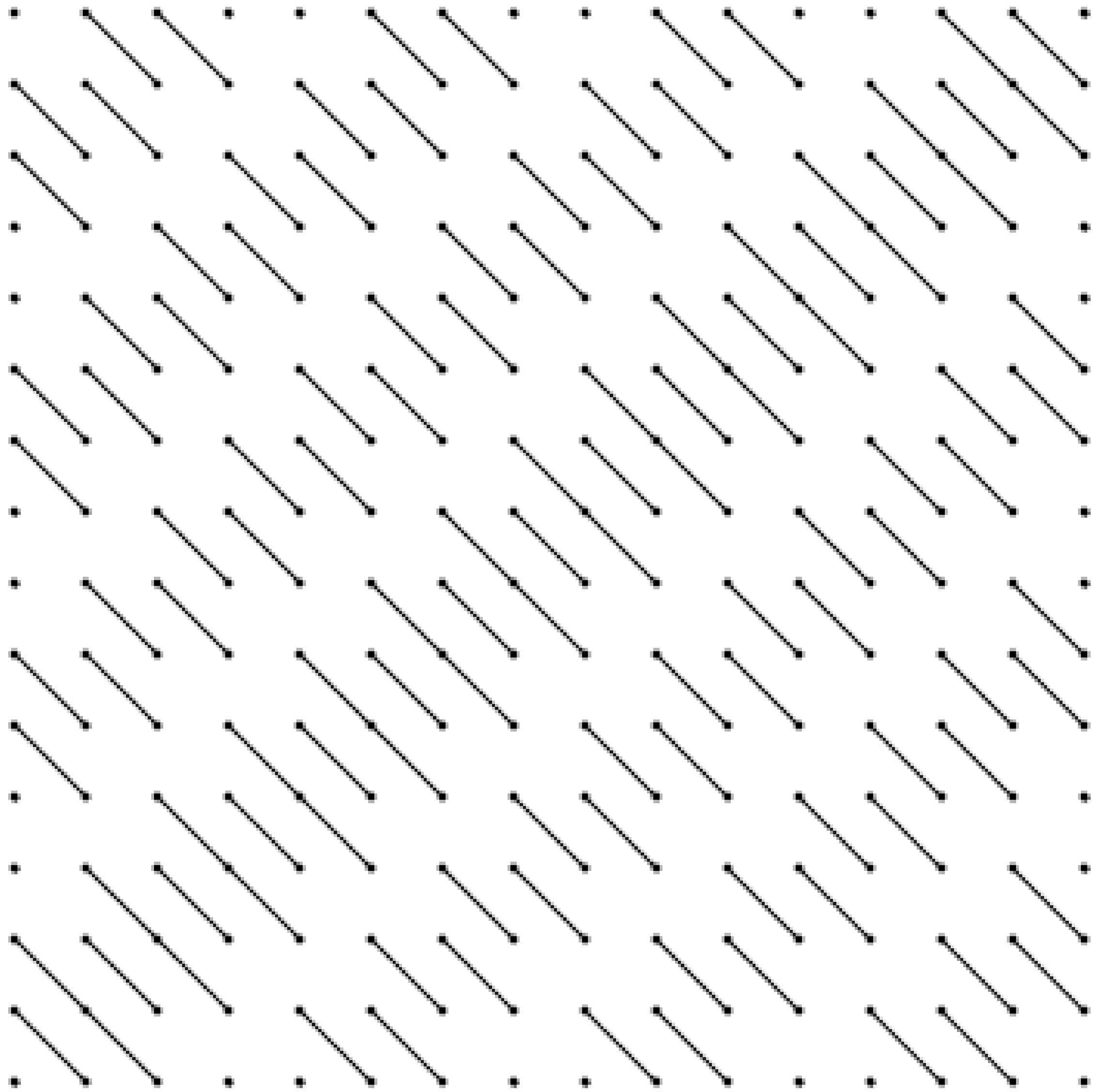

Figure 2: Michelogram with span=4.