FAST ADVANCED SCINTILLATION TIMING (2014-2018): http://www.cern.ch/FAST-COST

TD1401 EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Improvements in Data-Driven respiratory signal extraction with the use of TOF-PET data

Ottavia Bertolli, University College London, UK

2016 NSS-MIC: Workshop on the Technology Frontier for Single Photon Detection & Advanced Scintillator Timing

4th November, MIC 2016

Introduction

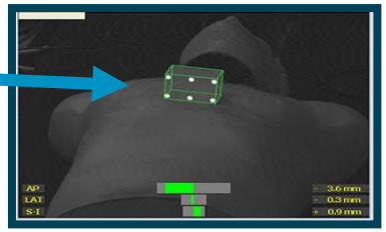
Respiratory motion results in blurring, degrading PET image quality and quantification:

- overestimation of the lesion size and volume;
- underestimation of lesion uptake;
- potential attenuation correction artefacts due to mismatch between images.

Respiratory motion correction is needed.

Clinical practice

RPM



Belt

Chest expansion

Data-Driven methods

Raw data → **DD** → signal

✓avoid use of external equipment
✓advantage of patient and operator convenience
✓potential increased fidelity to the internal movement

Principal Component Analysis

PCA is a general technique to describe the data as a combination of factors (**Principal Components**), that are ordered to explain **the maximum variation** in the data. The first factor will thus describe the biggest change in the data.

.

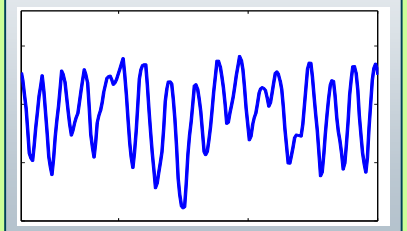
$$d(r,z,\phi,t) - \bar{d}(r,z,\phi) = \sum_k p_k(r,z,\phi) w_k(t)$$

Sinogram data

Empirical mean (projections)

Principal Components

Weight factors (time signals)



$$w_k(t) = \sum_{r,z,\phi} p_k(r,z,\phi) \cdot d(r,z,\phi,t)$$

Assumption: biggest changes in chest data caused by respiration.

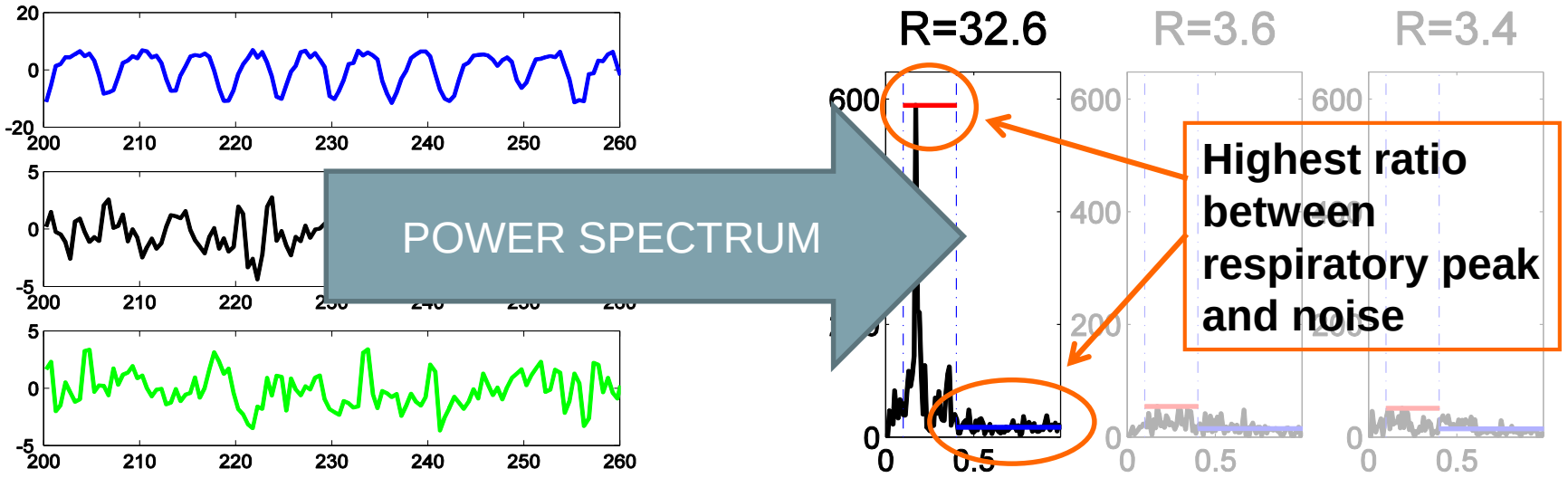
PCA applied on PET raw data:

$$p_k = p_1, p_2, p_3, \ldots$$

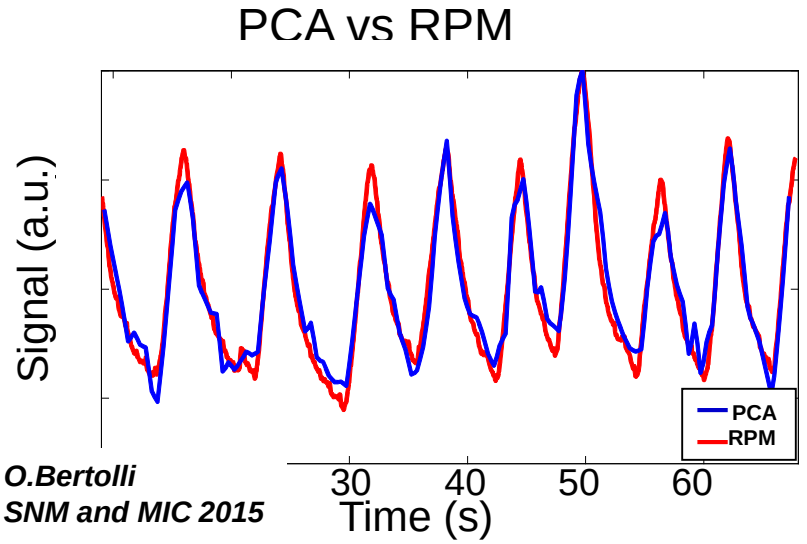
usually one of the first three PCs is representative of the respiratory motion, and its corresponding weight factor $\mathbf{w_k}$ is chosen as the **respiratory trace.**

Respiratory motion

PCA on PET raw data, chest bed position → consider the first 3 PCs

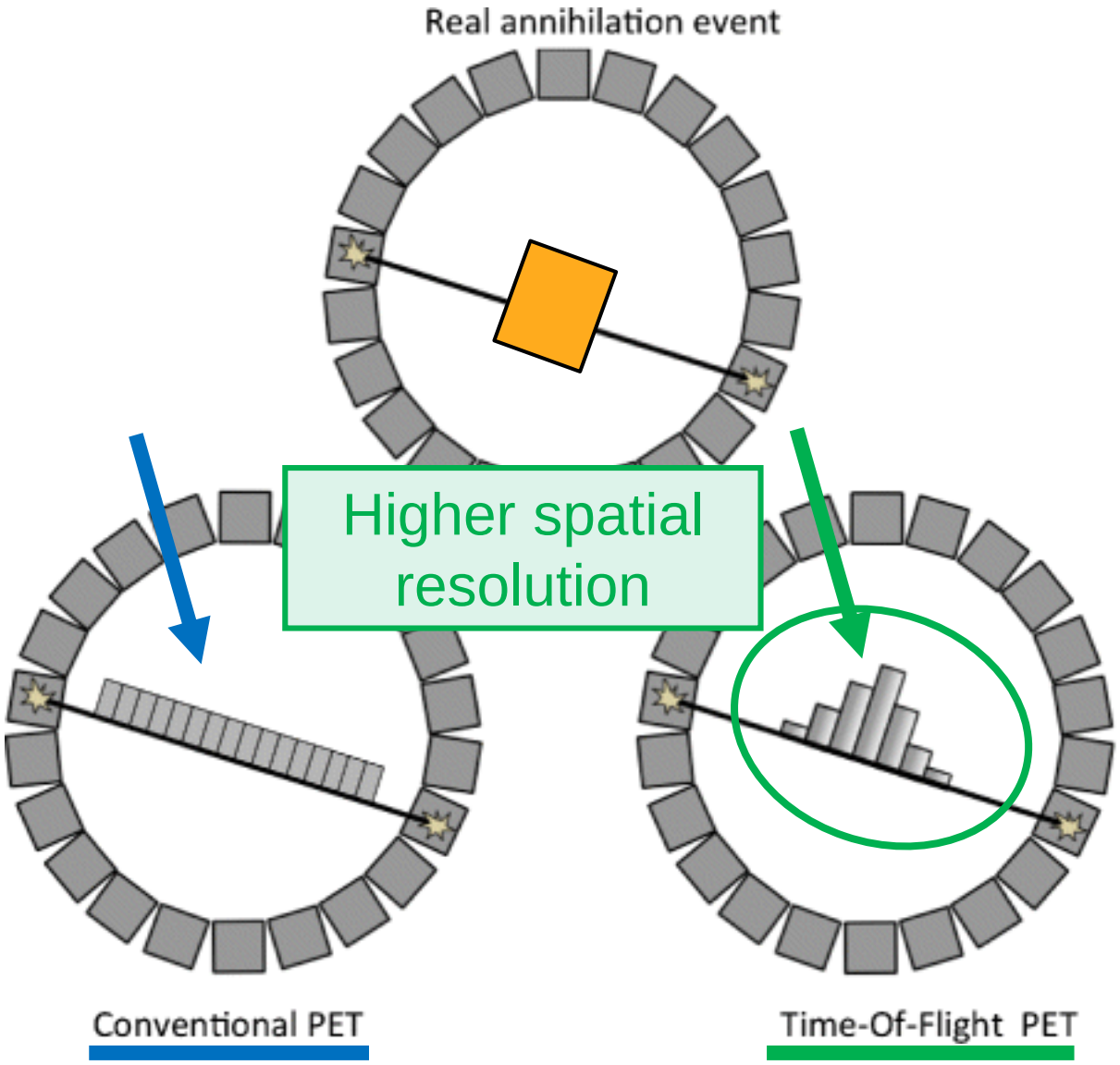


$$R = \frac{peak\ in\ resp\ band\ [0.1,0.4]Hz}{mean\ above\ 0.4\ Hz} = \frac{signal}{noise}$$



O.Bertolli
SNM and MIC 2015

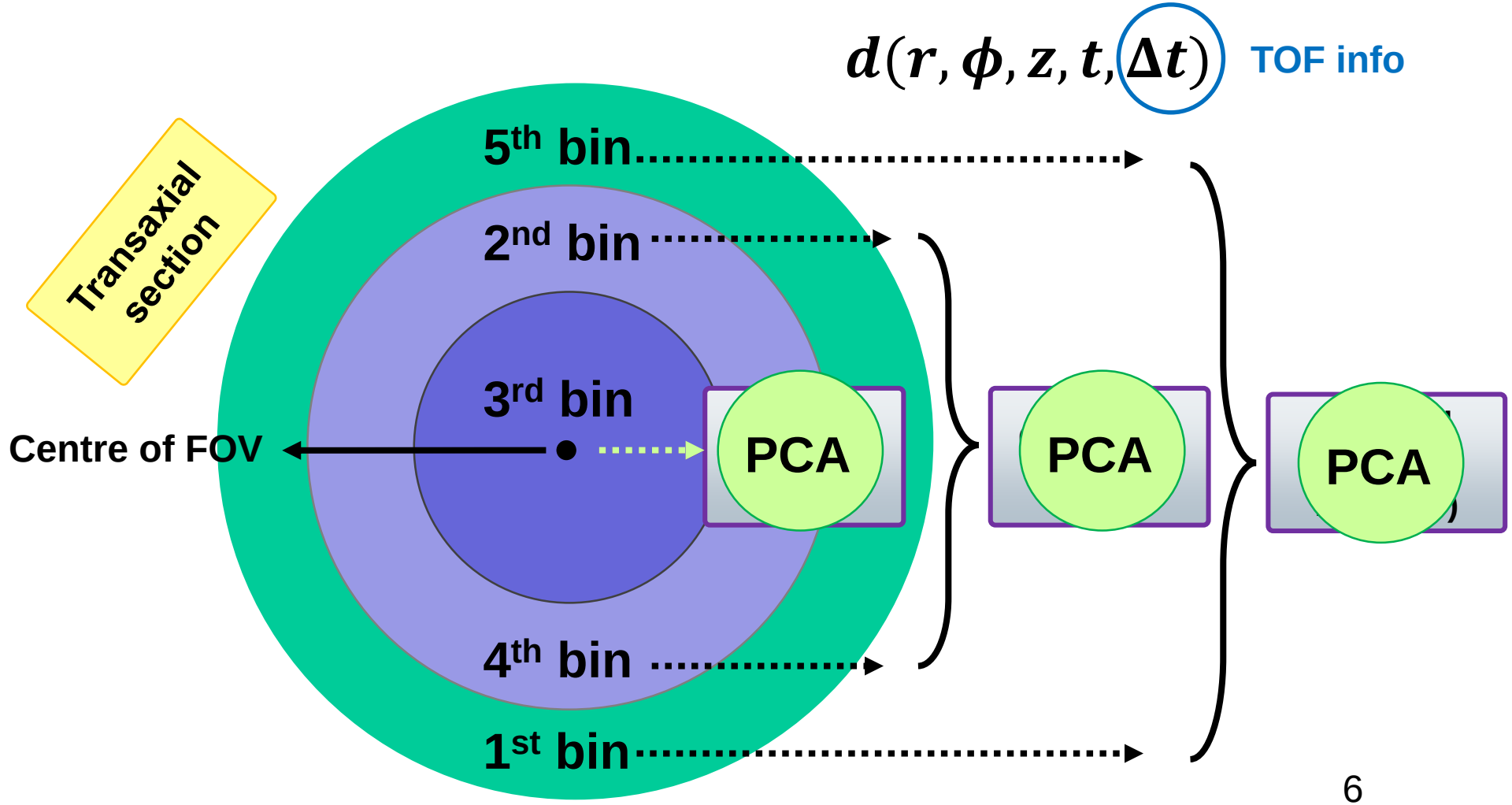
Exploiting Time-of-Flight information



Selecting TOF bins for PCA

•Different areas of the acquired data contribute to the respiratory signal to a different extent (center of the body, arms, etc..).

•**TOF information** allows us to **distinguish** between events that were generated in different regions of the FOV, **by selecting the TOF bins.**



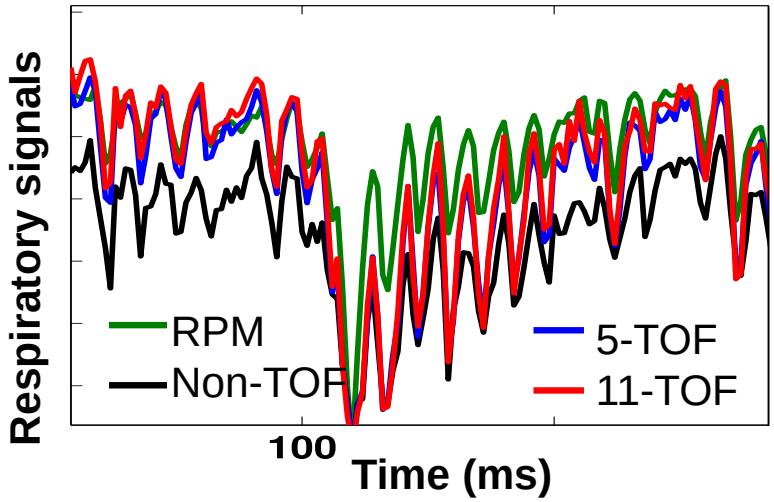
Evaluation

Data:

- 16 FDG oncology patients datasets, 3D listmode, GE Discovery 690 PET/CT;
- only the **chest bed position** was utilized (duration of 360 s);
- 550 ps TOF resolution, data acquired in **55 TOF bins of 89 ps width**;
- acquisitions were monitored by the RPM device;
- listmode files were unlisted with time frame duration of **500 ms into** non-TOF and TOF sinograms with a **total number of TOF bins of 5 or 11** (in which case, 11 and 5 TOF bins respectively were summed together).
- for the TOF-sinograms, PCA was also selectively applied on bins corresponding to areas equidistant from the centre.

Results

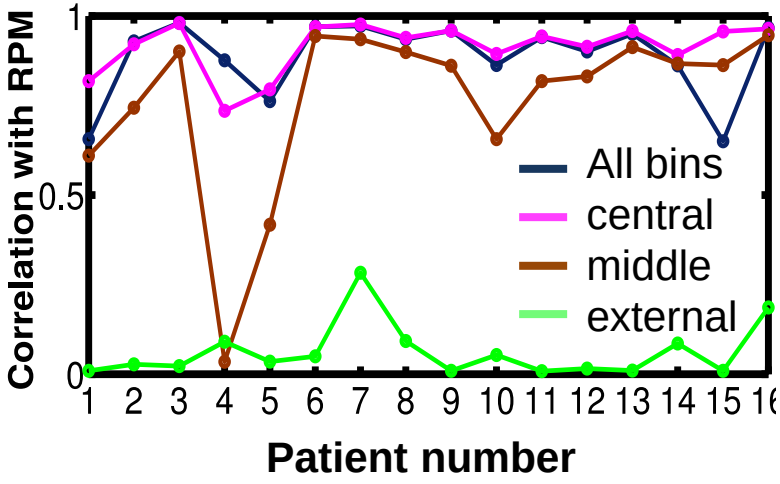
Non-TOF vs TOF



	non-TOF	5 TOF	11 TOF
R	21 ± 11	26 ± 11	27 ± 12
noise	180 ± 62	142 ± 40	124 ± 37
corr RPM	0.82 ± 0.14	0.91 ± 0.08	0.93 ± 0.06

R increases ✓ Noise decreases ✓Corr increases ✓

Selection of TOF bins



	5 TOF bins		
bins	**external**	**middle**	**central**
R	3 ± 0.2	15 ± 8	24 ± 10
noise	149 ± 47	118 ± 40	124 ± 37
corr RPM	0.82 ± 0.14	0.91 ± 0.08	0.93 ± 0.06

R increases ✓ Noise decreases ✓Corr increases ✓

Conclusions

- Exploiting the **TOF information** through rebinning the data into TOF sinograms evidently **improved the performance of PCA**.

- By selecting the **central TOF bins**, respiratory signals can be extracted directly from the **areas mostly affected by motion**, lowering the noise in the obtained signal.

Future developments:

- To further improve the selection of the area of interest for the application of **PCA**.

Acknowledgments

Supported by EPSRC Industrial CASE studentship 13220093, co-sponsored by GE Healthcare, and by the National Institute for Health Research, University College London Hospitals Biomedical Research Centre.

UCL:

Kris Thielemans
Simon Arridge
Brian Hutton

GE Healthcare Research, Waukesha, WI, USA:

Chuck Stearns
Scott Wollenweber

FAST ADVANCED SCINTILLATION TIMING (2014-2018): http://www.cern.ch/FAST-COST