



»» TRANSFORMING PROMISING IDEAS INTO COMMERCIAL REALITY

Determination of Body Sway Area by Fourier Analysis of its Contour

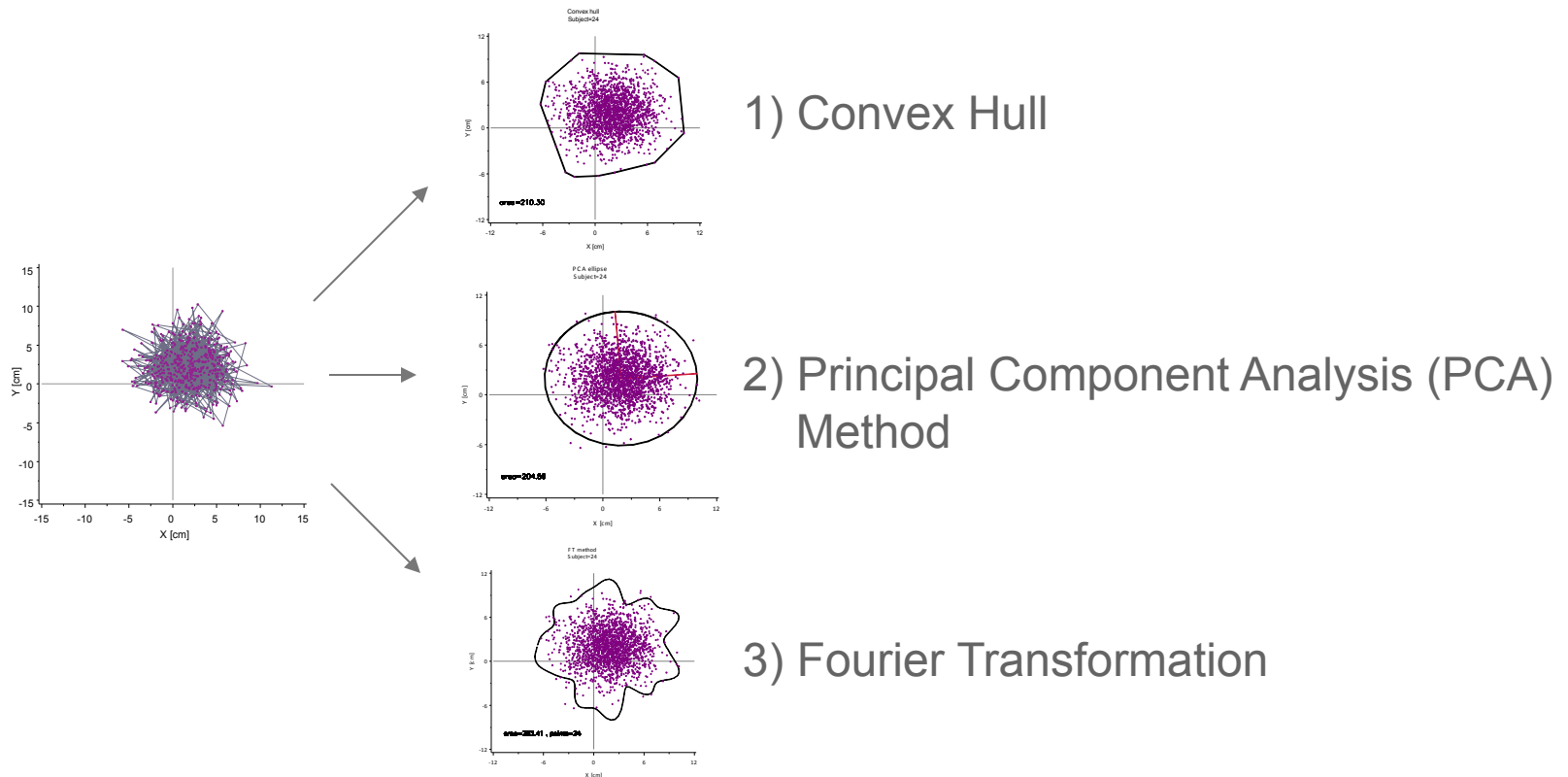
Thomas Wollseifen

PhUSE Brussels, Belgium, 2013 October 13th-16th



Content

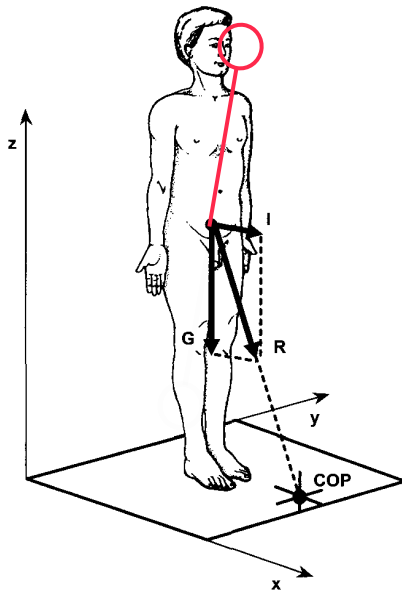
- Posturography
- Calculation of body sway outline



- Comparison



Posturography

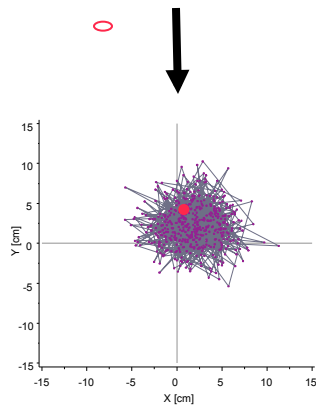


Balance disorders

- Unsteadiness
- Dizziness
- Feeling of movement, spinning or floating

Posturography

- Test of balance
 - Quantify postural control in upright stance
 - Patient in standing posture on force platform
- Body sway area, length of path, velocity

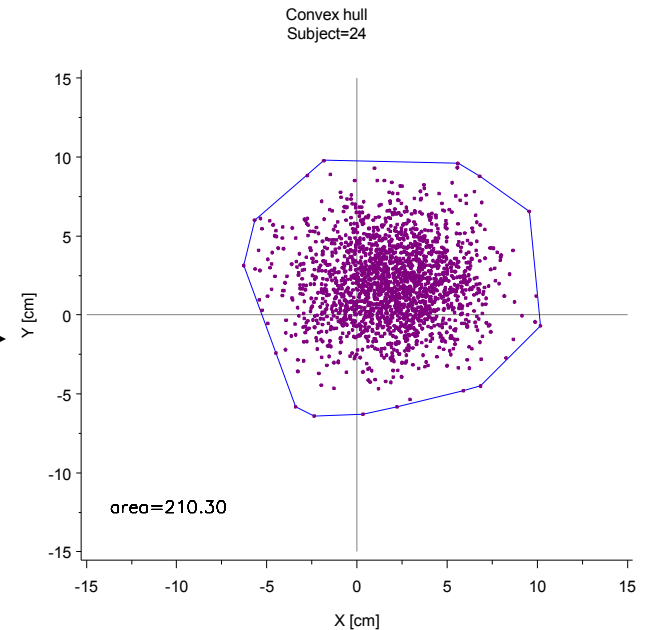
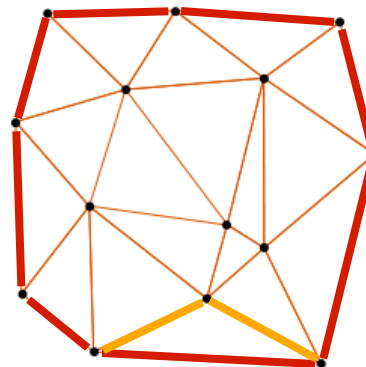




Convex hull

`proc g3grid data=... outtri=... → triangulation of data set`
`&y.*&x.=&z;`

ys	xs	TRIANGLE TRIANGLE NUMBER
9.785	-1.83	3903
8.532	-0.118	3904
9.785	-1.83	3904
9.303	0.972	3904
8.788	6.803	3905
9.331	5.571	3905
9.597	5.601	3905
8.839	-2.747	3906
9.785	-1.83	3906
8.911	-1.473	3906
9.303	0.972	3907
9.785	-1.83	3907
9.597	5.601	3907
-6.388	-2.371	3908
.	.	3908
.	.	3908
-6.388	-2.371	3909
-5.801	-3.402	3909
.	.	3909





Principal component analysis (PCA)

```
proc princomp data=pca01 COV OUT =_prins;
```

```
var &y. &x.;
```

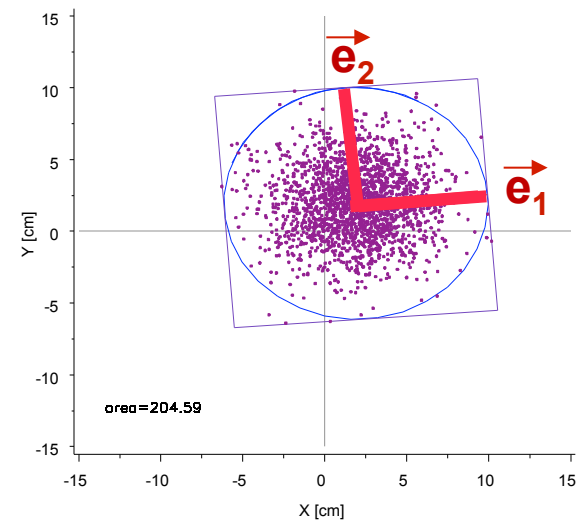
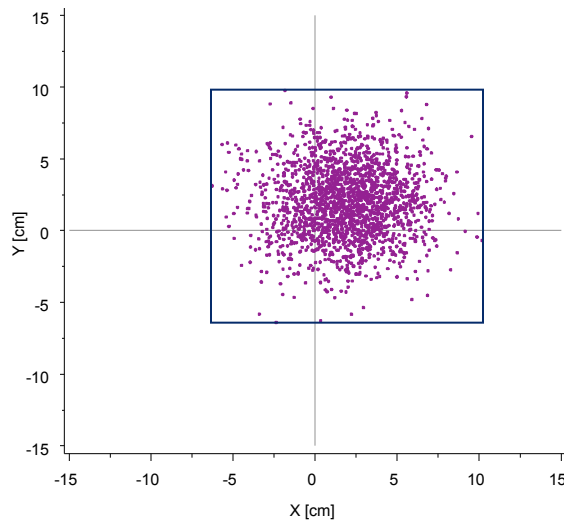
```
run;
```



Covariance-Matrix

Cov(y,y)	Cov(y,x)
Cov(x,y)	Cov(x,x)

Eigenvectors $\vec{e}_1$, $\vec{e}_2$



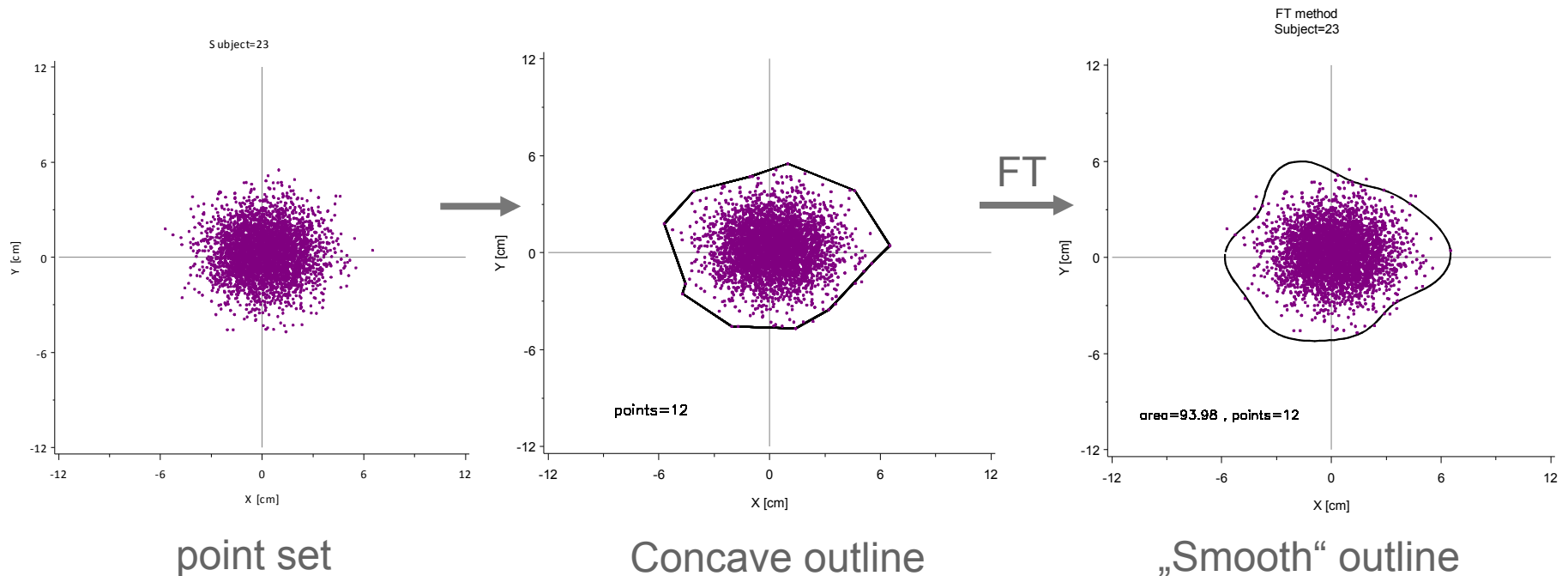


Calculation of contour with Fourier Transformation

`%macro fouriertransform(points=, accuracy=);`

Given Point set

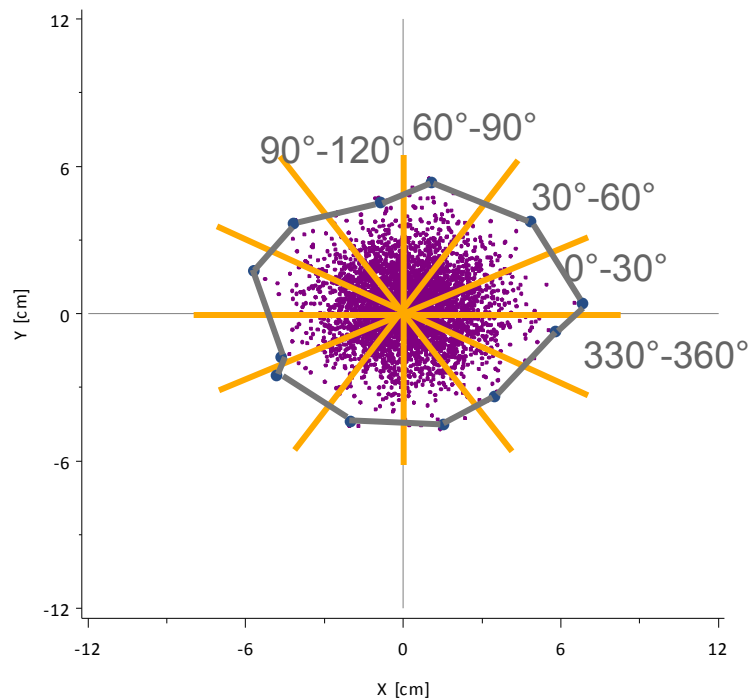
- 1) Calculate concave outline → first approximation
- 2) Fourier transformation → Proc Spectra
- 3) Calculate ‚smooth‘ outline





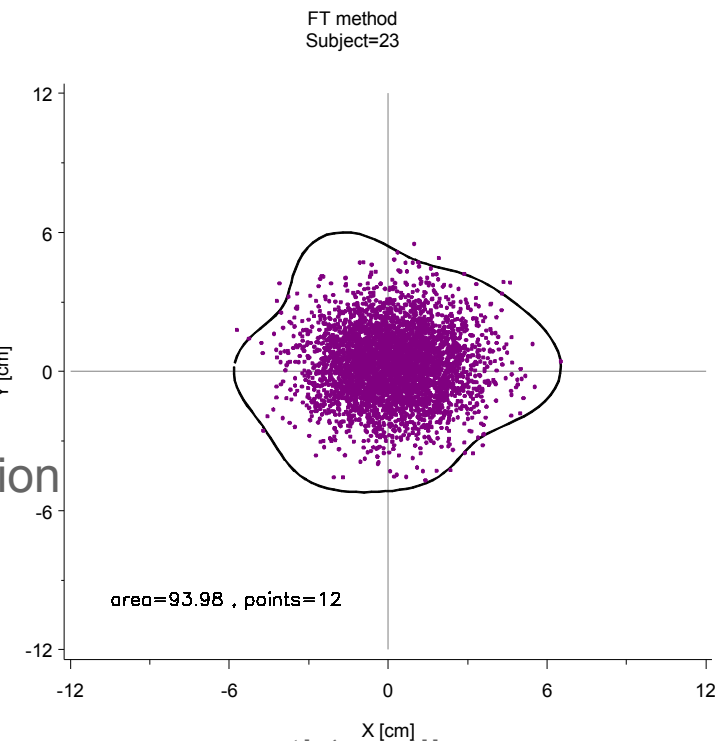
Concave outline

- 1) Transform cartesian coordinates (x_i, y_i) to polar coordinates (r_i, ϕ_i)
- 2) Divide full revolution into m intervalls ($360^\circ/m$)
- 3) $\text{Max}(r_i)$ from center of pressure (cx_i, cy_i) is first approximation of outline



Concave outline

Fourier
Transformation



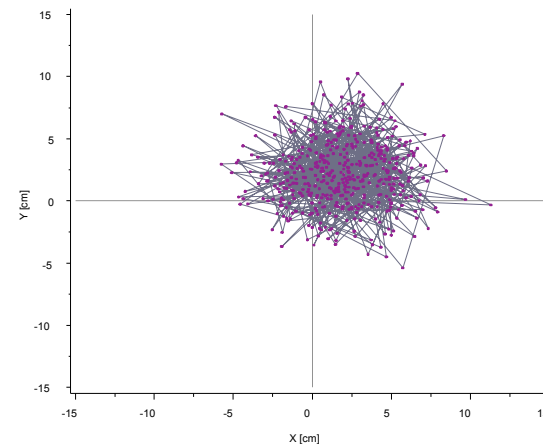
,smooth' outline



Fourier Series

- **Fourier series** decomposes periodic functions or periodic signals into the sum of a (possibly infinite) set of simple oscillating functions

$$f(x_t) = \underbrace{\frac{A_0}{2}}_{\text{Fourier coefficient}} + \sum_{k=1}^m \left[\underbrace{A_k}_{\text{Fourier coefficients}} \cos(\varpi_k t) + \underbrace{B_k}_{\text{Fourier coefficients}} \sin(\varpi_k t) \right]$$





Determination of Fourier Coefficients with SAS

```
proc  spectra data=ft out=fouriercoeff1 coef;  
var r ;  
by usubjid;  
run;
```

FREQ Frequency from 0 to PI	PERIOD Period	A_m	B_m	P_01 Periodogram of r	i
		COS_01 Cosine Transform of r	SIN_01 Sine Transform of r		
0		$A_0 = 14.6$	0	1907.4	1
0.3	18	$A_1 = -0.1$	$B_1 = 0.4$	1.3	2
0.7	9	$A_2 = 0.1$	$B_2 = -0.7$	4.2	3
1	6	-0.1	-0.3	0.8	4
1.4	4.5	0.1	-0.4	1.5	5
1.7	3.6	0.7	-0.3	5.3	6
2.1	3	-0.4	-0.2	1.8	7
2.4	2.6	-0.5	0	2.4	8
2.8	2.3	-0.3	0.4	2.5	9
3.1	2	$A_9 = -0.5$	$B_9 = 0$	2.3	10



Calculation of contour with Fourier Transformation

%macro fouriertransform(npoints= , accuracy=0.04);

- 1) Calculation of concave outline
- 2) Calculation of Fourier coefficients (of radius r) → Proc Spectra;
- 3) Calculation of (r_m, ϕ_m) based on Fourier coefficients A_m and B_m

Do $\Phi = -\pi$ to π by &accuracy;

$$R(\Phi) = \frac{R_0}{2} + \sum_{m=2}^{m_{\max}} [A_m \cos(m\Phi) + B_m \sin(m\Phi)]$$

End;

- 4) Re-Transformation of polar coordinates to cartesian coordinates
→ smooth outline



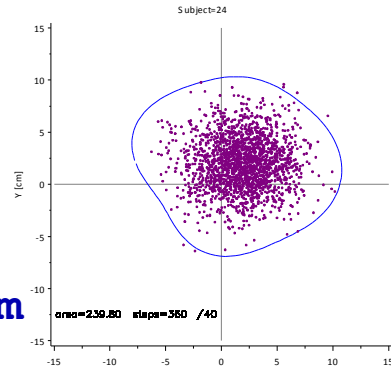
Parameterized macro %fouriertransform

```
%fouriertransform
```

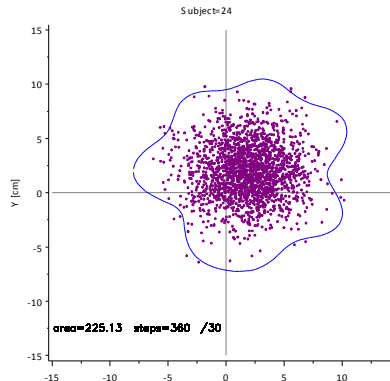
```
(indata=,
```

```
  npoints=30,
```

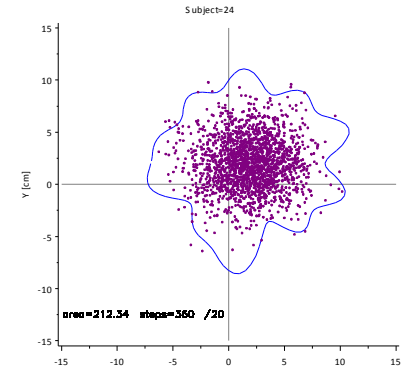
```
  accuracy=0.04);
```



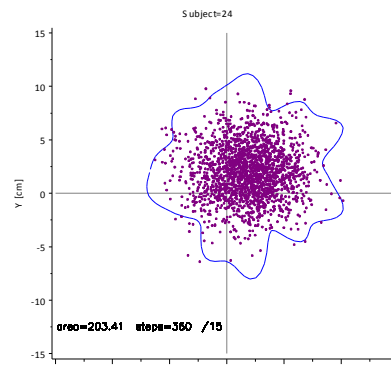
9 points / A=240



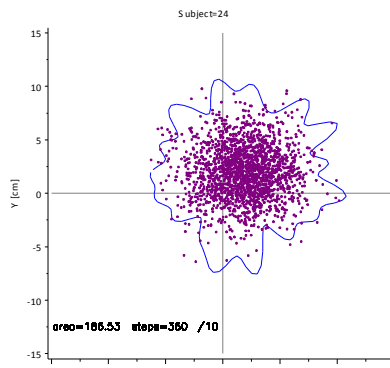
12 points / A=225



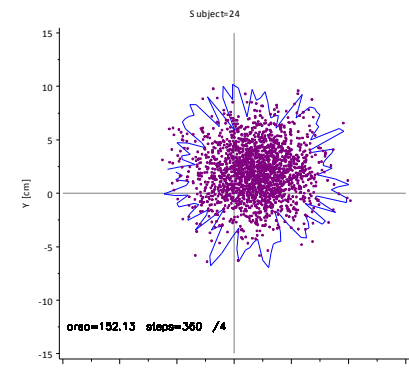
18 points / A=212



24 points / A=203



36 points / A=187

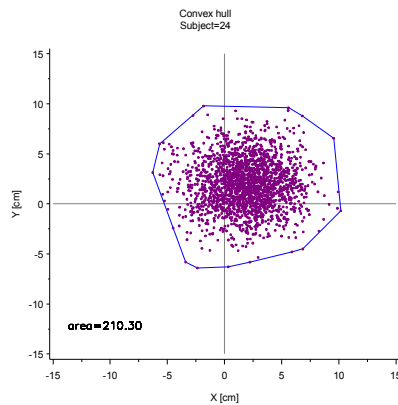


90 points / A=152



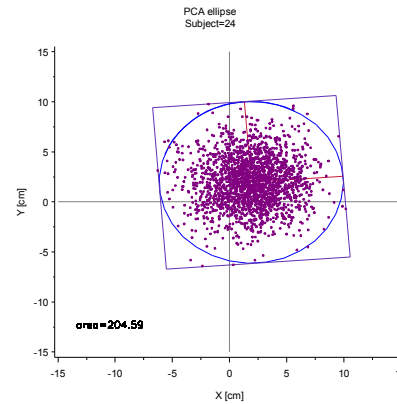
COMPARISON

Convex hull



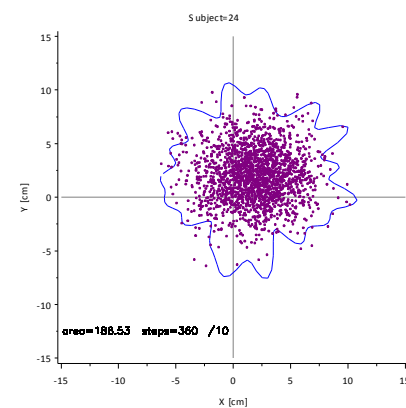
$$A_{CH}=210,30 \text{ [cm}^2\text{]}$$

PCA method



$$A_{PCA}=204,6 \text{ [cm}^2\text{]}$$

Fourier transformation



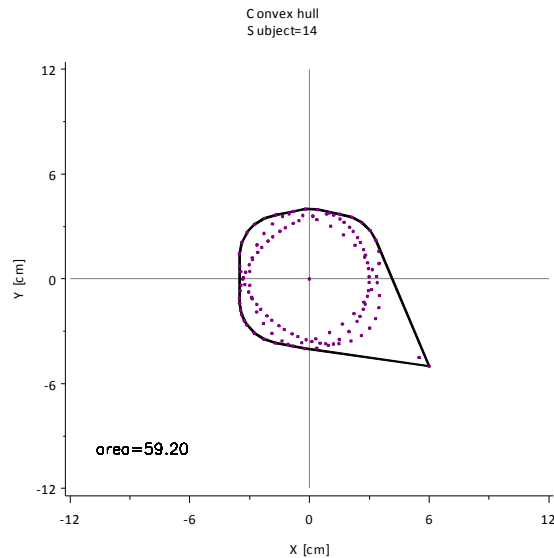
$$A_{FT}=186.5 \text{ [cm}^2\text{]}$$

→ Area depends
on number of points



Effect of outliers

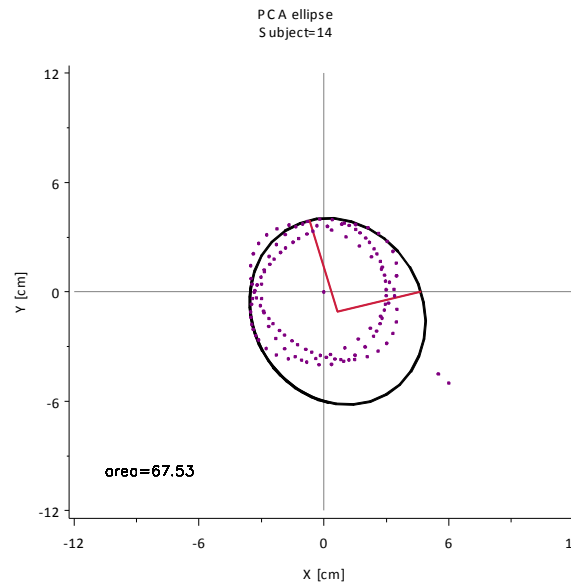
Convex hull



Area=59.2

large influence of outliers
→ all points are enclosed
→ larger area

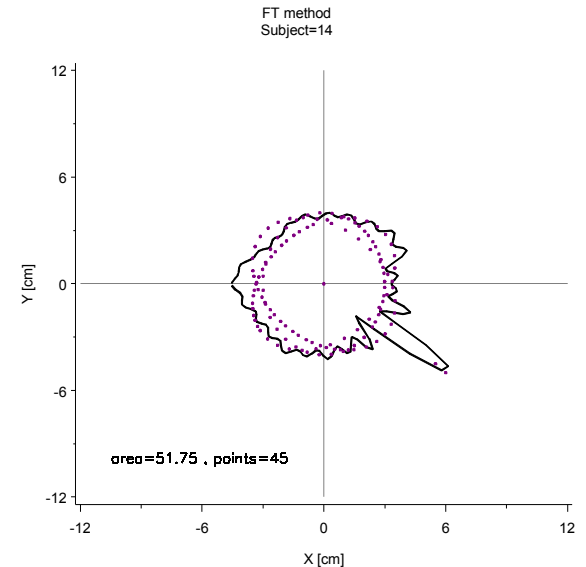
PCA method



Area=67.5

large influence of outliers
→ „tries“ to enclose all points

Fourier transformation



Area=51.8

Small influence of Outliers → „loop“



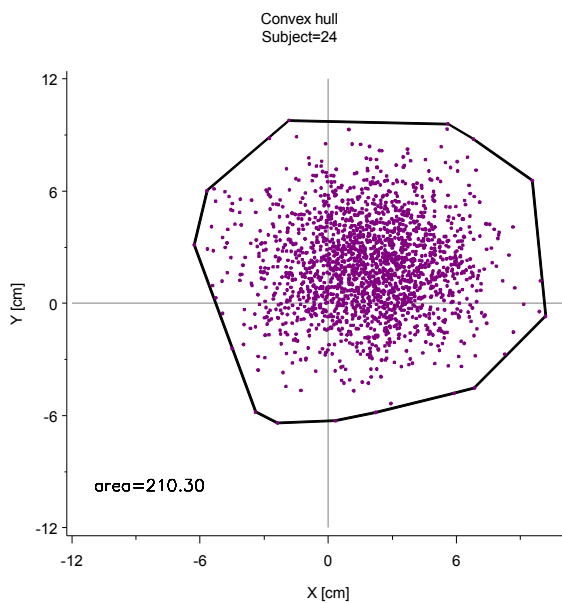
Summary

	Shape	Area	Outliers	Parameterized
Convex hull	good outline No details	Good approximation All points included	Not invariant	No
PCA method	No details →Ellipse angle/direction	Rough approximation	Not invariant	No
FT method	Details	Approximation of the ,true area' Depend on points used	Limited influence →loops	Yes

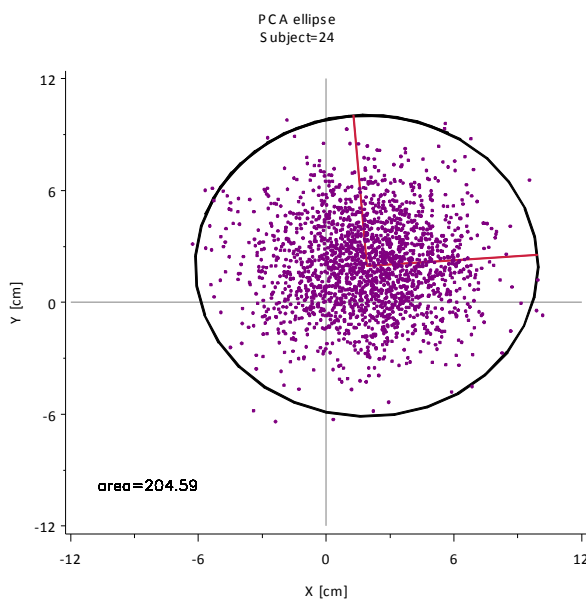


Questions & Answers

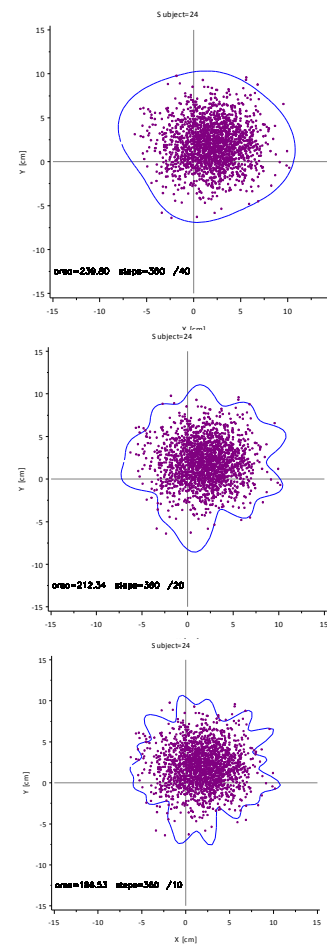
Convex hull



PCA method



Fourier transformation





Links / Literature

- [1] http://en.wikipedia.org/wiki/Balance_disorder
- [2] Rugelj, D.; Sevsek, F.: Postural sway area of elderly subjects, WSEAS transactions on signal processing, 2007, vol. 3, iss. 2, str. 213-219.
- [3] Wollseifen, T.: Different Methods of Calculating Body Sway Area, Pharmaceutical Programming, vol. 5, numbers 1-2, 12/2011, pp. 91-106(16).
- [4] [sas.support.com,](http://support.sas.com/documentation/cdl/en/etsug/60372/HTML/default/viewer.htm#etsug_spectr__sect001.htm)
http://support.sas.com/documentation/cdl/en/etsug/60372/HTML/default/viewer.htm#etsug_spectr__sect001.htm



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