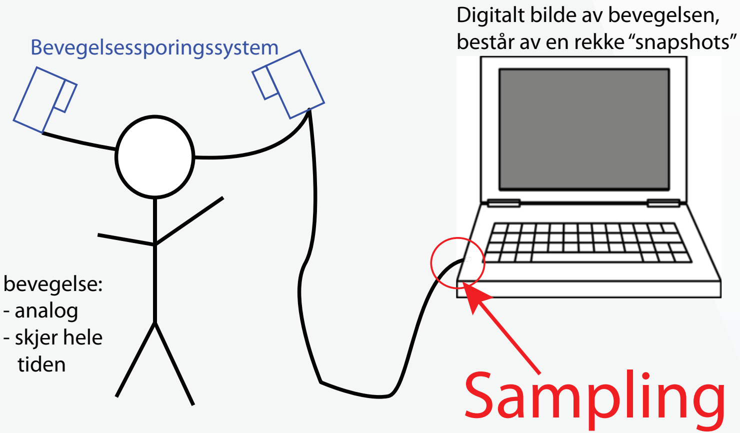
# Bevegelsessporing

MUS2006 - Musikk og bevegelse

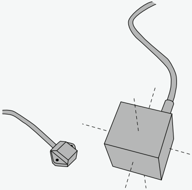
5 mars 2015

# Analog → Digital: Sampling

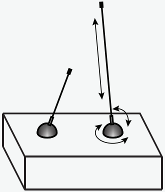



- I virkeligheten skjer en bevegelse hele tiden
- En datamaskin kan ikke forholde seg til analoge data, og må sample den analoge bevegelsen et visst antall ganger per sekund.

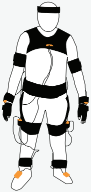
# Body motion: Tracking technologies



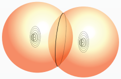
Magnetic



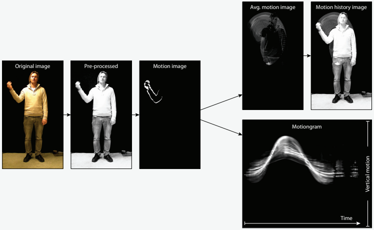
Mechanical



Inertial



acoustic




Optical markerless

Optical marker-based

# Ulike kvalitetsmål på motion capture systemer:

- Oppløsning: Vi kan for eksempel ikke studere hoftebevegelsene til en sambadanser med et GPS system som har en oppløsning på ca 3 meter.
- Samplingshastighet: Hvis du gjør bare én måling hvert sekund kan det skje mye bevegelse som du ikke fanger opp. Vanlig hastigheter for optiske systemer er mellom 100 og 1000 målinger per sekund (Hz, fps)
- Støy
- Drift
- Stabilitet (kan f.eks. sensoren plutselig falle av?)
- Jitter (Gjøres det målinger med jevne tidsmellomrom?)

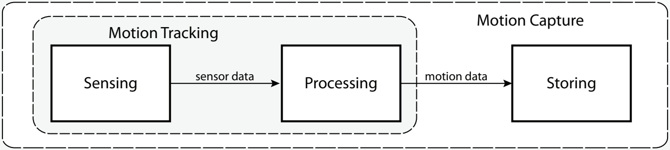
# Body motion: Tracking technologies

| | Inertial/ magnetic | Mechanical | Electro-magnetic | Optical (visual) | Optic (infrared) | Physiological |
|---|---|---|---|---|---|---|
| + | - flexible<br>- small | - flexible<br>- small | - resolution<br>- identification<br>- absolute | - flexible<br>- no cables<br>- no markers<br>- accessible | - speed<br>- resolution<br>- # markers | - indirect motion sensing |
| - | - relative | - relative | - cable<br>- short range | - 2D<br>- speed<br>- resolution<br>- identification | - markers<br>- calibration<br>- identification | - indirect motion sensing |

Fra Jensenius, Nymoen, Godøy (2008)

# Motion Capture / Bevegelsessporing

- *Sensing* the motion
- *Processing* the the sensor data
- *Storing* the data



# Sensing

# Body motion: Sensing technologies

- Mechanical sensing
- Force sensing
- Acoustic sensing
- Inertial sensing
- Electromagnetic sensing
- Physiological sensing
- Optical sensing

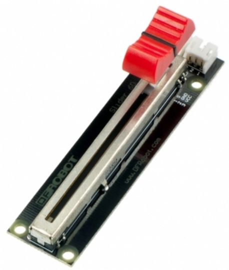
# Body motion: Sensing technologies

- Mechanical sensing
- Force sensing
- Acoustic sensing
- Inertial sensing
- Electromagnetic sensing
- Physiological sensing
- Optical sensing

We'll go into a bit more detail on a few of these

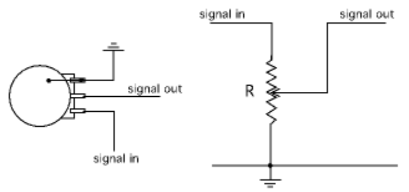
# Mechanical sensing: Potentiometers and sliders

Potentiometer / potmeter

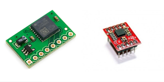


Slider

Concept: Electricity in → Scaling → Scaled electricity out



# Inertial sensing: Accelerometers and Gyroscopes

Tiny chips found in every smart phone these days: 

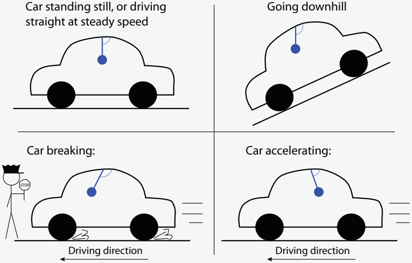
Accelerometer:
measures acceleration, including:

- Gravity
- Change in speed
- Change in direction

Gyroscope:
measures rotation, meaning:

- Change in direction

Conceptual example:




More difficult to illustrate, but you may know the concept from some everyday objects:

# Optical sensing: Video

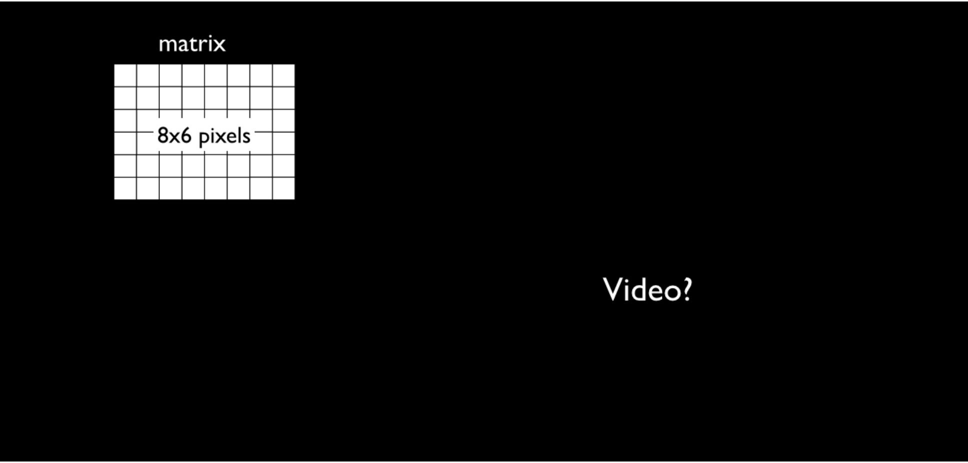



Illustration by Alexander Refsum Jensenius

# Optical sensing: Video

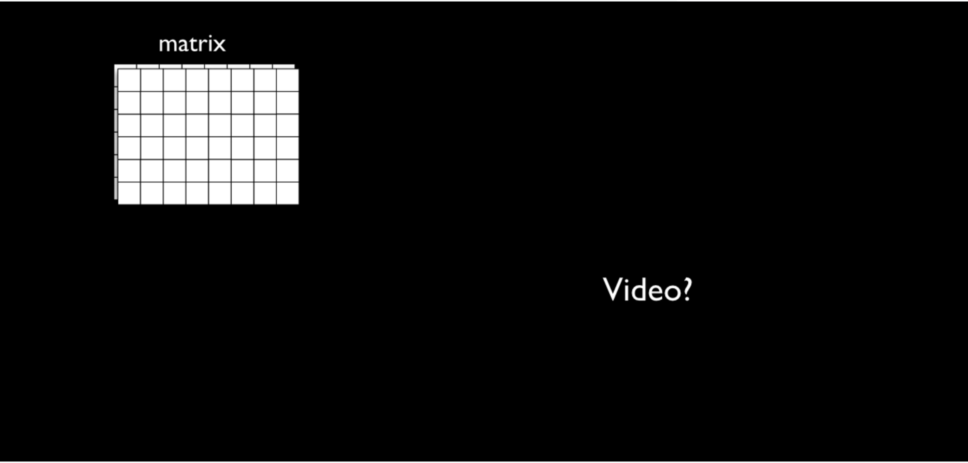



Illustration by Alexander Refsum Jensenius

# Optical sensing: Video

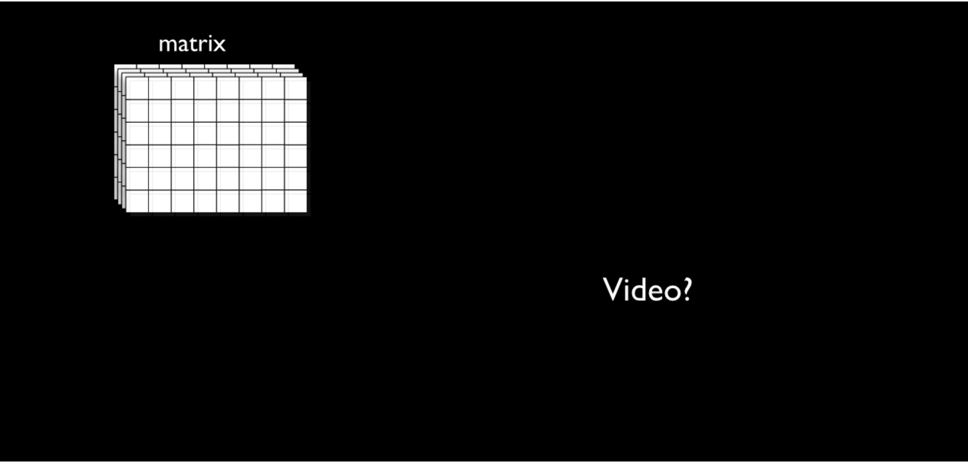



Illustration by Alexander Refsum Jensenius

# Optical sensing: Video

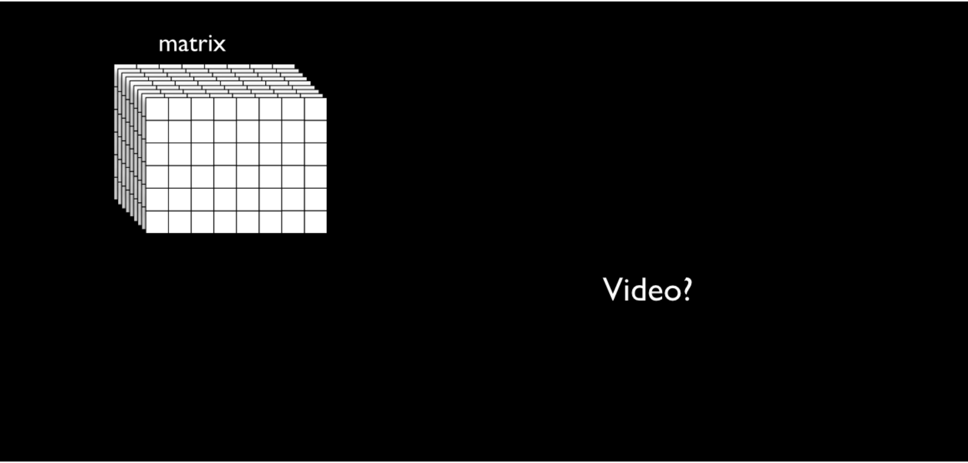



Illustration by Alexander Refsum Jensenius

# Optical sensing: Video

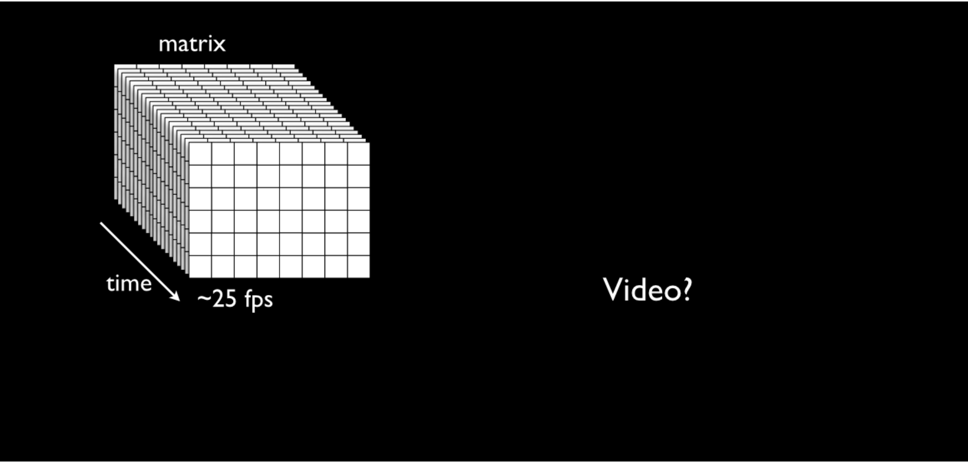
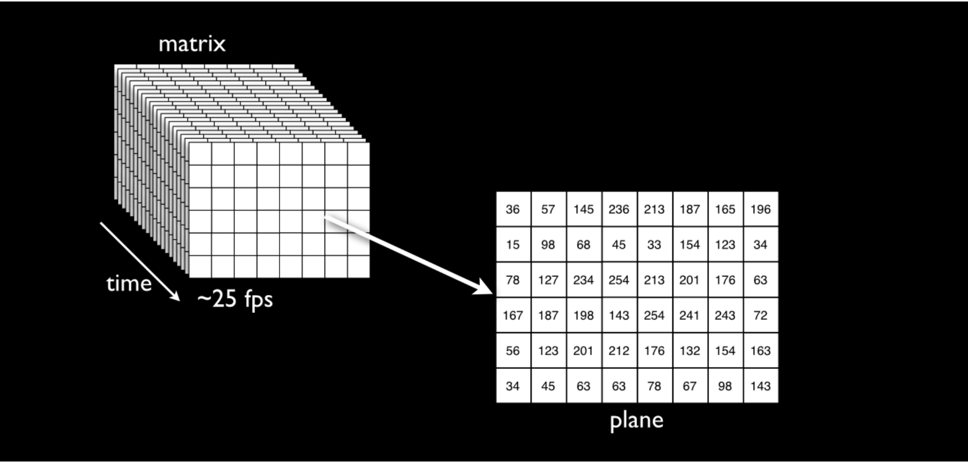



Illustration by Alexander Refsum Jensenius

# Optical sensing: Video




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 36 | 57 | 145 | 236 | 213 | 187 | 165 | 196 |
| 15 | 98 | 68 | 45 | 33 | 154 | 123 | 34 |
| 78 | 127 | 234 | 254 | 213 | 201 | 176 | 63 |
| 167 | 187 | 198 | 143 | 254 | 241 | 243 | 72 |
| 56 | 123 | 201 | 212 | 176 | 132 | 154 | 163 |
| 34 | 45 | 63 | 63 | 78 | 67 | 98 | 143 |

Illustration by Alexander Refsum Jensenius

# Optical sensing: Video

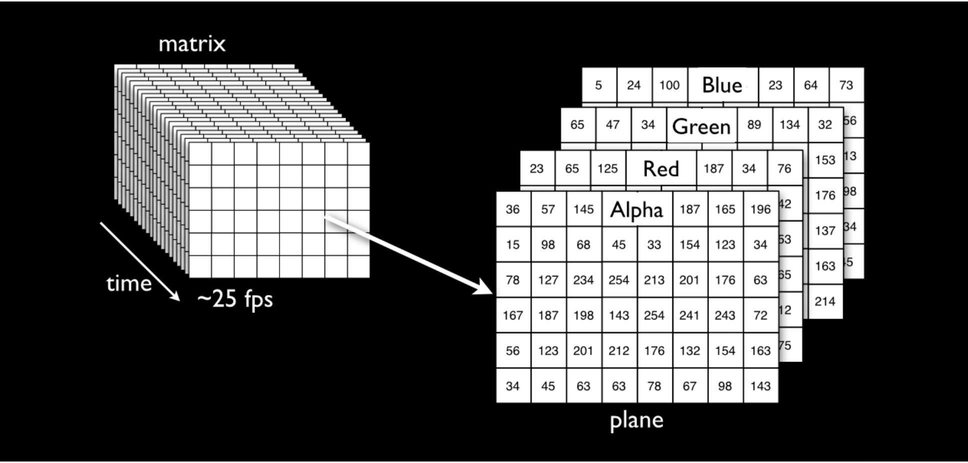



Illustration by Alexander Refsum Jensenius

# Tracking

# Optical tracking: Blob detection

Example task: Find the red ball:

Red plane

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 2 | 4 | 2 | 1 | 1 | 2 | 2 | 2 | 4 | 2 | 5 | 2 | 2 | 2 |
| 6 | 1 | 5 | 2 | 2 | 2 | 2 | 2 | 12 | 2 | 2 | 2 | 3 | 2 | 2 |
| 2 | 3 | 2 | 9 | 7 | 8 | 2 | 2 | 2 | 2 | 6 | 2 | 7 | 2 | 2 |
| 0 | 2 | 6 | 2 | 3 | 2 | 3 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | 2 |
| 2 | 1 | 0 | 2 | 0 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| 2 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 32 | 43 | 22 | 12 | 2 | 2 |
| 2 | 0 | 2 | 2 | 2 | 2 | 2 | 50 | 199 | 197 | 192 | 90 | 12 | 2 | 0 |
| 2 | 2 | 1 | 2 | 9 | 3 | 2 | 20 | 180 | 201 | 200 | 198 | 2 | 3 | 1 |
| 2 | 1 | 0 | 2 | 2 | 2 | 2 | 21 | 232 | 194 | 210 | 199 | 2 | 2 | 2 |
| 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 64 | 2 | 2 | 2 | 2 | 0 |

# Optical tracking: Blob detection

Example task: Find the red ball:

Green plane

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 2 | 5 | 2 | 2 | 2 | 4 | 2 | 4 | 2 | 1 | 1 | 2 | 2 | 2 |
| 2 | 2 | 2 | 3 | 2 | 2 | 6 | 1 | 5 | 2 | 2 | 2 | 2 | 2 | 12 |
| 2 | 6 | 2 | 7 | 2 | 2 | 2 | 3 | 2 | 9 | 7 | 8 | 2 | 2 | 2 |
| 2 | 3 | 2 | 2 | 2 | 2 | 0 | 2 | 6 | 2 | 3 | 2 | 3 | 2 | 1 |
| 2 | 2 | 2 | 2 | 2 | 0 | 2 | 1 | 0 | 2 | 0 | 2 | 2 | 1 | 2 |
| 3 | 0 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 2 |
| 6 | 1 | 2 | 1 | 2 | 0 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 5 | 1 |
| 1 | 0 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 2 | 9 | 3 | 2 | 7 | 1 |
| 4 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 2 | 2 | 2 | 1 | 3 |
| 4 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 |

# Optical tracking: Blob detection

Example task: Find the red ball:

Blue plane

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 2 | 2 | 4 | 2 | 5 | 2 | 2 | 2 | 4 | 2 | 4 | 2 |
| 2 | 2 | 2 | 2 | 12 | 2 | 2 | 2 | 3 | 2 | 2 | 6 | 1 | 5 | 2 |
| 7 | 8 | 2 | 2 | 2 | 2 | 6 | 2 | 7 | 2 | 2 | 2 | 3 | 2 | 9 |
| 3 | 2 | 3 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | 2 | 0 | 2 | 6 | 2 |
| 0 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 1 | 0 | 2 |
| 2 | 2 | 3 | 2 | 2 | 3 | 0 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 3 |
| 2 | 2 | 2 | 5 | 1 | 6 | 1 | 2 | 1 | 2 | 0 | 2 | 0 | 2 | 2 |
| 9 | 3 | 2 | 7 | 1 | 1 | 0 | 1 | 2 | 3 | 1 | 2 | 2 | 1 | 2 |
| 2 | 2 | 2 | 1 | 3 | 4 | 0 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 2 |
| 2 | 2 | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 4 |

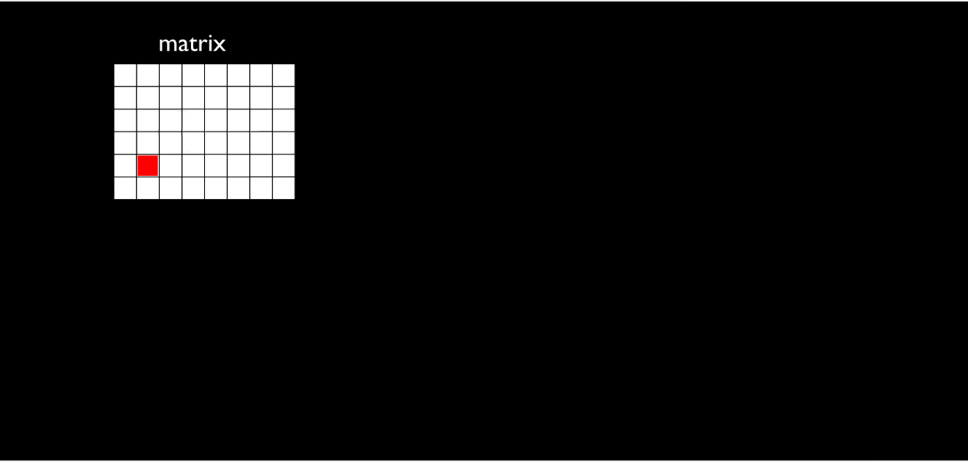
# Optical tracking: Blob detection

Example task: Find the red ball:

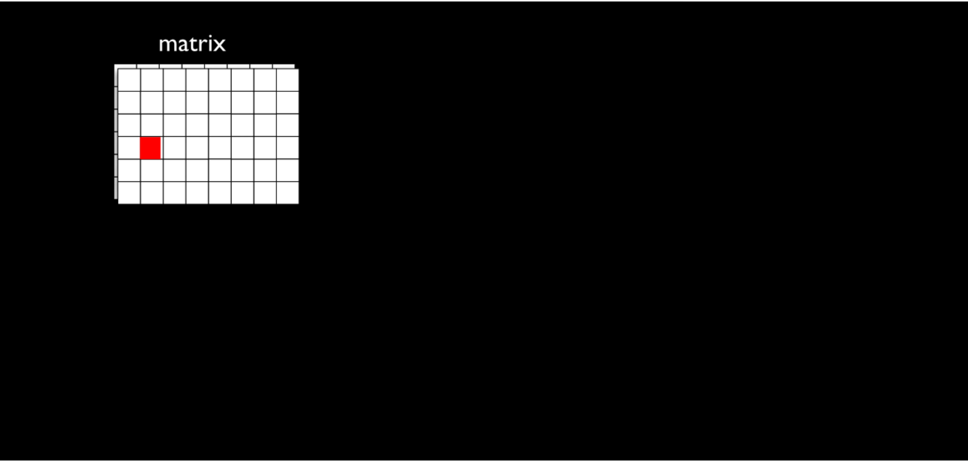
Red plane

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 2 | 4 | 2 | 1 | 1 | 2 | 2 | 2 | 4 | 2 | 5 | 2 | 2 | 2 |
| 6 | 1 | 5 | 2 | 2 | 2 | 2 | 2 | 12 | 2 | 2 | 2 | 3 | 2 | 2 |
| 2 | 3 | 2 | 9 | 7 | 8 | 2 | 2 | 2 | 2 | 6 | 2 | 7 | 2 | 2 |
| 0 | 2 | 6 | 2 | 3 | 2 | 3 | 2 | 1 | 2 | 3 | 2 | 2 | 2 | 2 |
| 2 | 1 | 0 | 2 | 0 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| 2 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 32 | 43 | 22 | 12 | 2 | 2 |
| 2 | 0 | 2 | 2 | 2 | 2 | 2 | 50 | 199 | 197 | 192 | 90 | 12 | 2 | 0 |
| 2 | 2 | 1 | 2 | 9 | 3 | 2 | 20 | 180 | 201 | 200 | 198 | 2 | 3 | 1 |
| 2 | 1 | 0 | 2 | 2 | 2 | 2 | 21 | 232 | 194 | 210 | 199 | 2 | 2 | 2 |
| 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 64 | 2 | 2 | 2 | 2 | 0 |

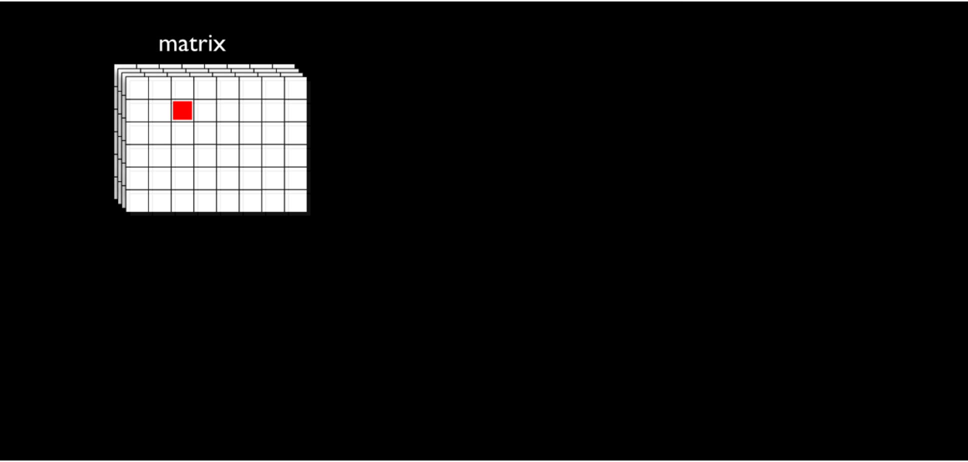
# Optical tracking: From position to trajectory



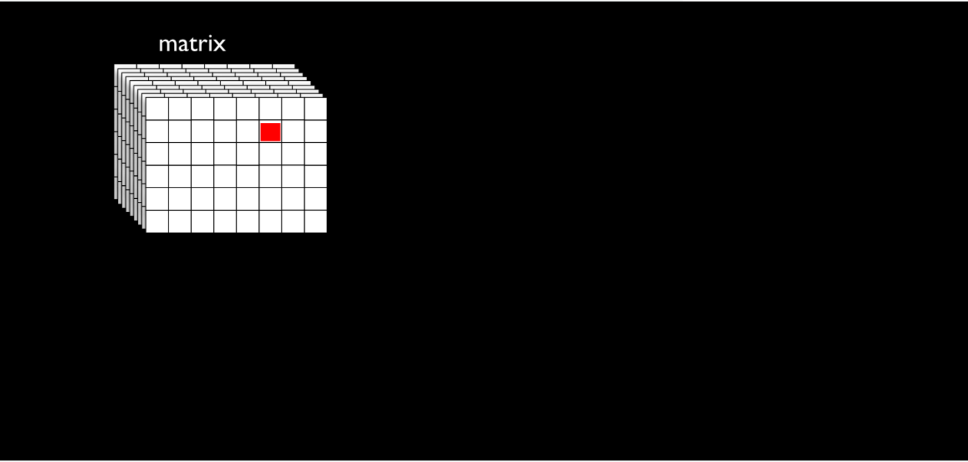
# Optical tracking: From position to trajectory



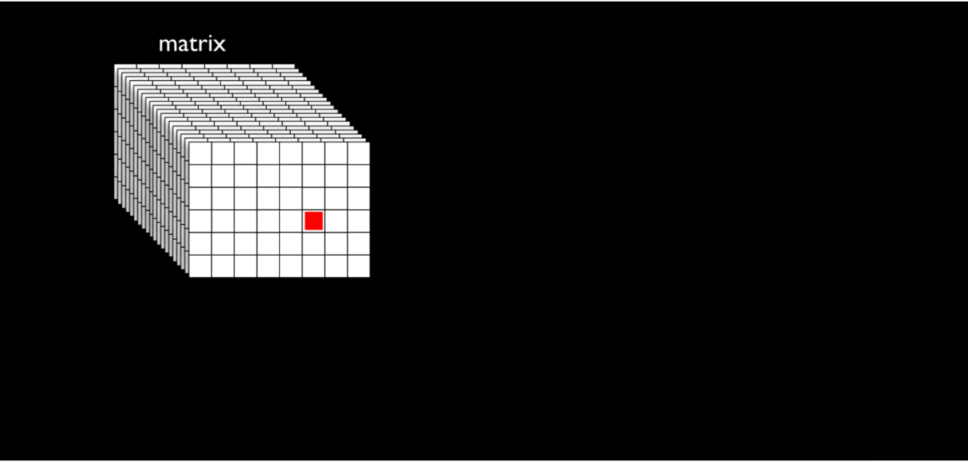
# Optical tracking: From position to trajectory



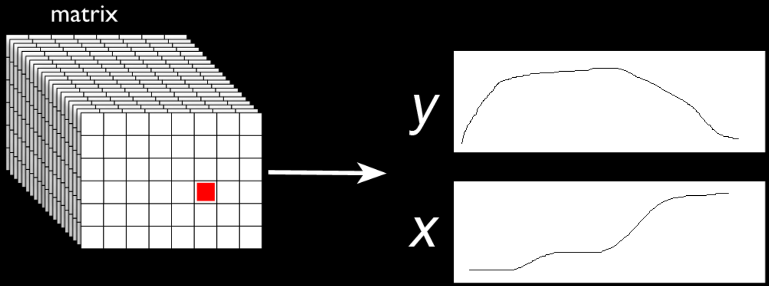
# Optical tracking: From position to trajectory



# Optical tracking: From position to trajectory

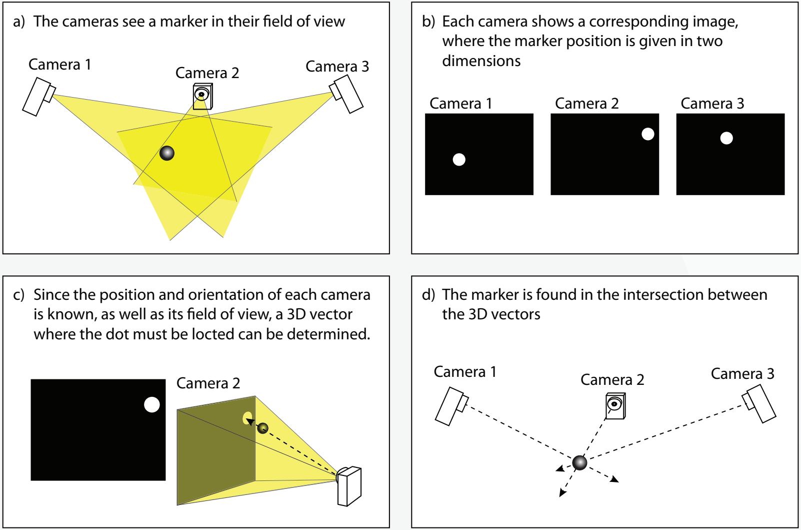


# Optical tracking: From position to trajectory



# Optical Marker-Based Motion Capture

# Optical Marker-Based Motion Capture



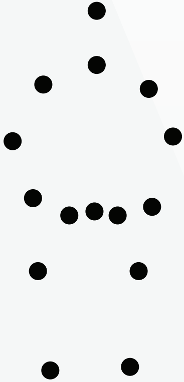
# Optical Marker-Based Motion Capture

Systems available at UiO:

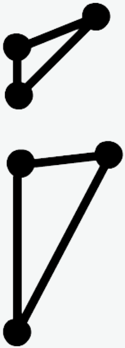

Qualisys

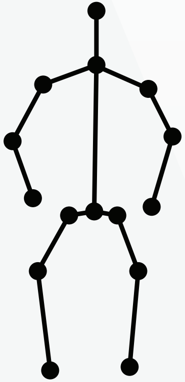

OptiTrack

# Markers — Rigid bodies — Kinematic chains

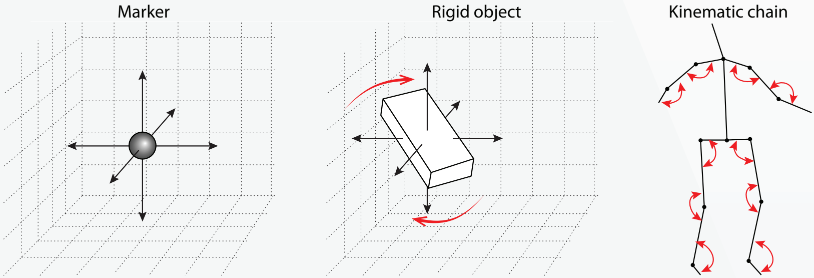


# Markers — Rigid bodies — Kinematic chains



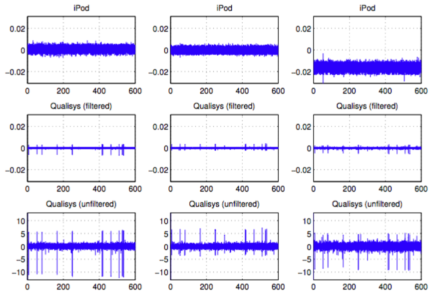


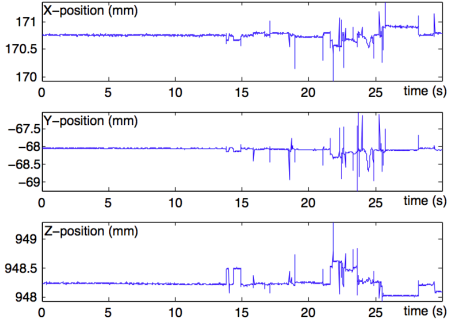
# Markers — Rigid bodies — Kinematic chains

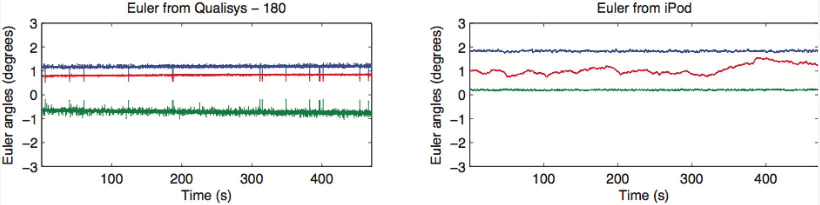


# Processing motion data

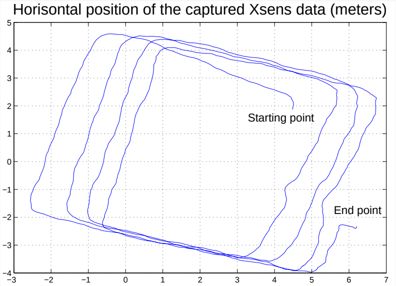
# All data contains noise!

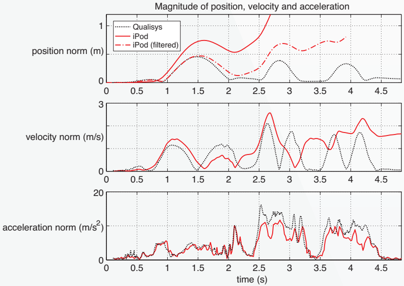


# Drift in inertial systems



# Preprocessing: Gap-filling

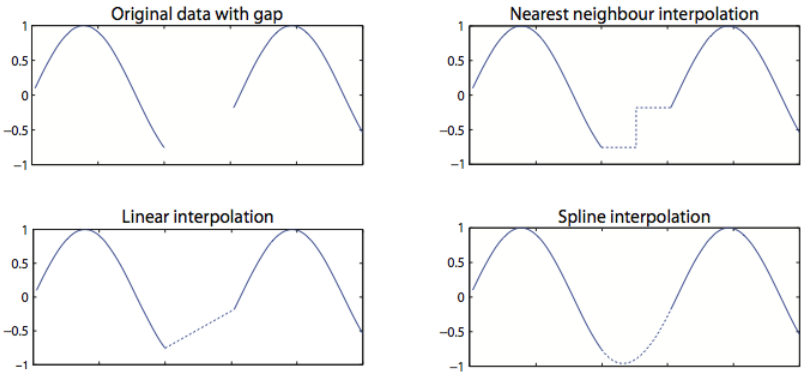
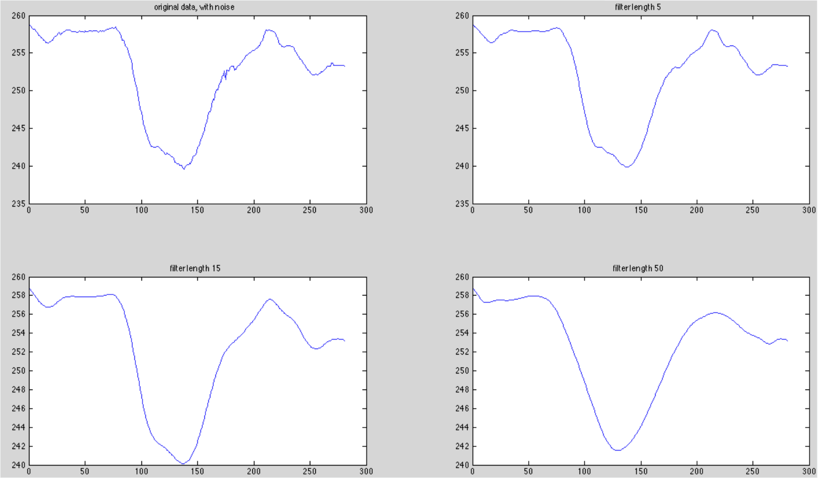



**Figure 3.13:** Three techniques for gap-filling: nearest neighbour, linear and spline.

# Preprocessing: Smoothing



# Visualization:

Typical plot of XYZ data of one marker. Not so intuitive...

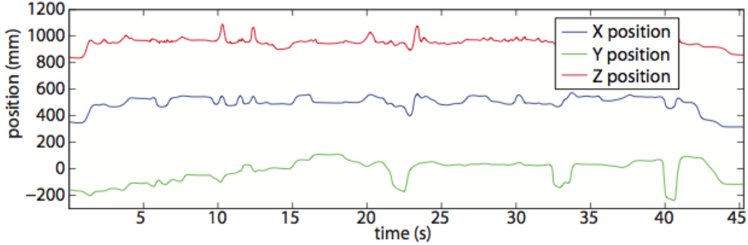



**Figure 4.2:** A common way of plotting three-dimensional marker data in time and space.

# Visualization:

Another option: Putting X, Y and Z on different axes, and let colour denote time

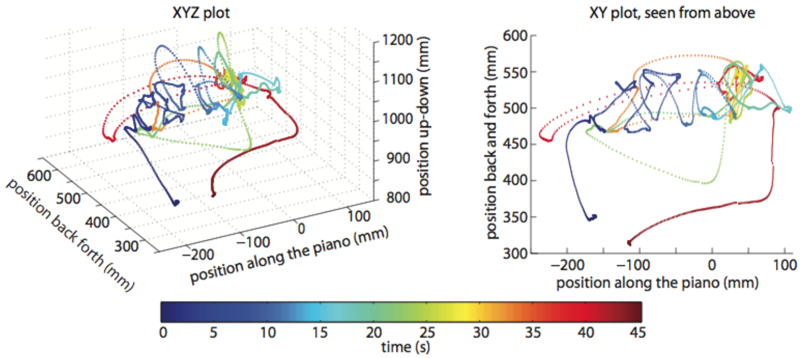
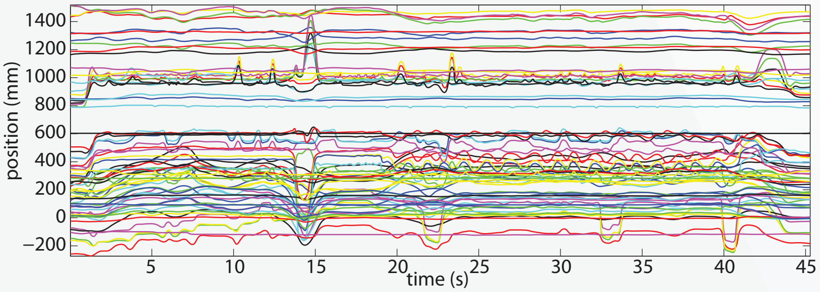



**Figure 4.6:** The trajectory of a single marker can be shown in 2D or 3D plots. Time can be shown by colour-coding the trajectory. The marker shown in the plots is the same right wrist marker as in Figure 4.2.

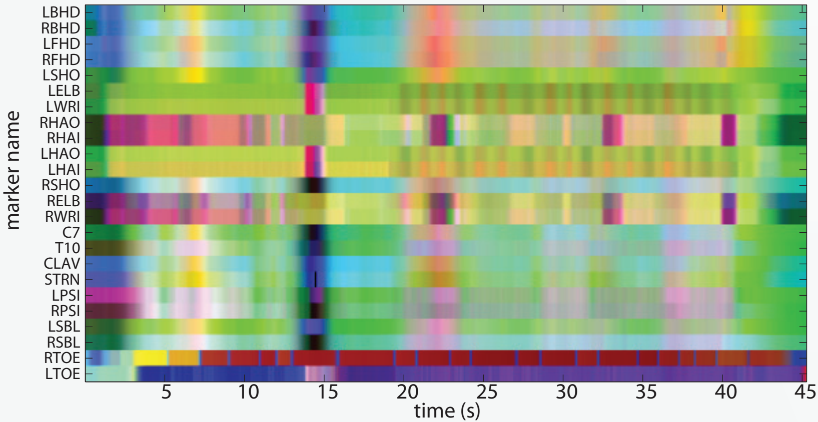
# Visualization:

Plotting many (24) xyz marker positions can get really messy



# Visualization:

Another option is to use colour coding: Mocapgrams



# Position – Hastighet – Akselerasjon

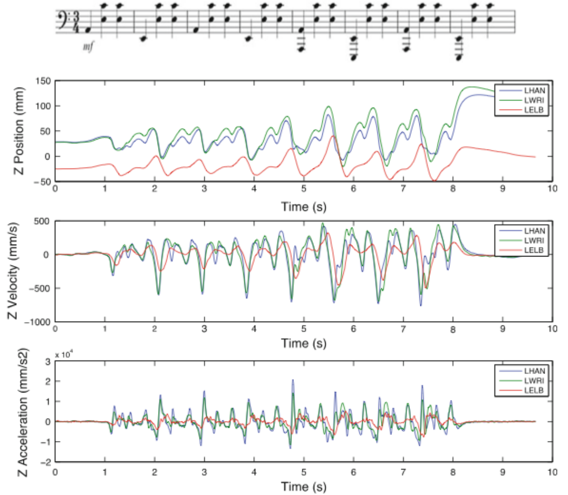
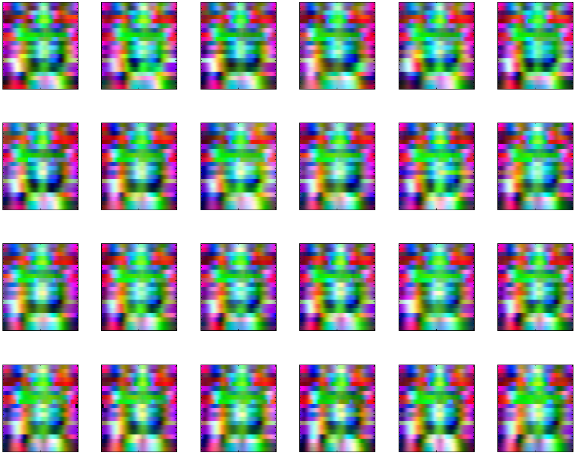
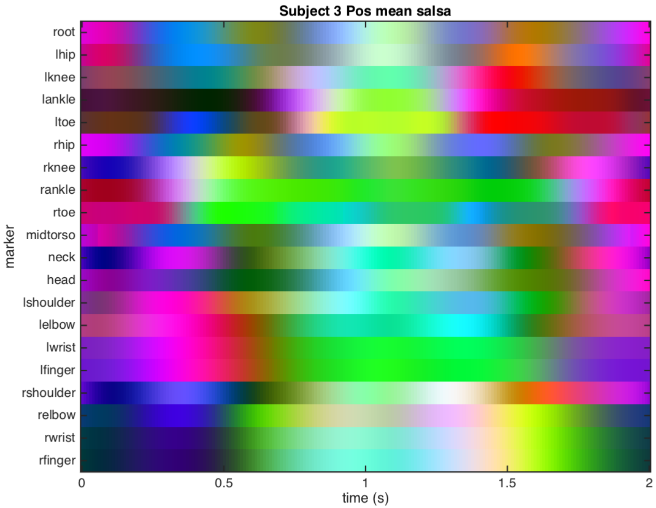
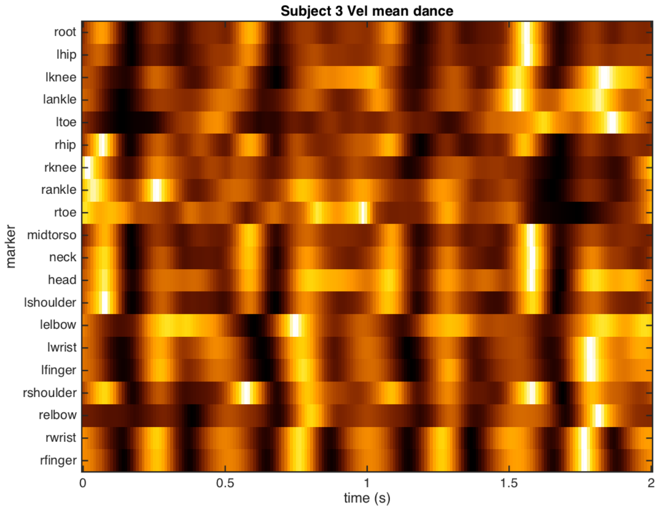


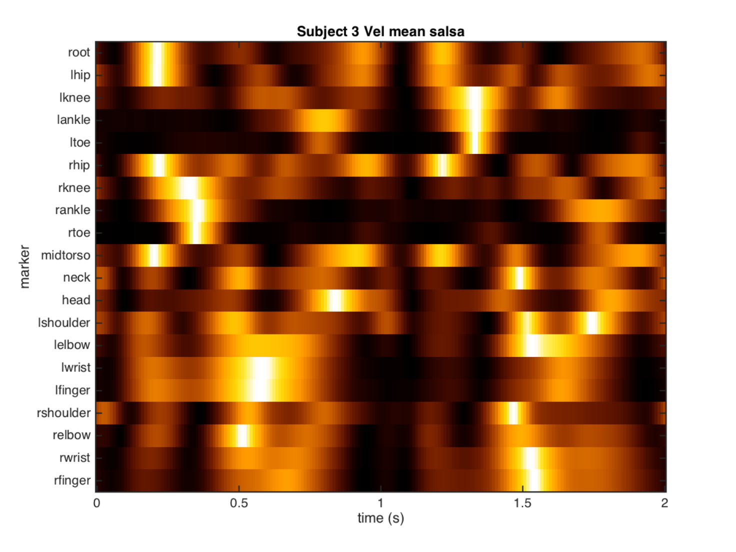

**Fig. 1** A waltz-like fragment for the *piano* for *left hand solo*, with notation (*top*), and underneath this, motion trajectories of hand, wrist, and elbow along the *vertical plane*, and underneath this again, the velocity and acceleration plots of this motion data

Figure from:
R.I.Godøy. "Quantal Elements in Musical Experience" in R. Bader(ed.), *Sound Perception Performance, Current Research in Systematic Musicology* 1, Springer 2013.




Subject 3 Pos mean salsa
root
lhip
lknee
lankle
ltoe
rhip
rknee
rankle
rtoe
midtorso
neck
head
lshoulder
lelbow
lwrist
lfinger
rshoulder
relbow
rwrist
rfinger
marker
0
0.5
1
1.5
2
time (s)


Subject 3 Vel mean dance
marker
root
lhip
lknee
lankle
ltoe
rhip
rknee
rankle
rtoe
midtorso
neck
head
lshoulder
lelbow
lwrist
lfinger
rshoulder
relbow
rwrist
rfinger
0
0.5
1
1.5
2
time (s)


Subject 3 Vel mean salsa
root
lhip
lknee
lankle
ltoe
rhip
rknee
rankle
rtoe
midtorso
neck
head
lshoulder
lelbow
lwrist
lfinger
rshoulder
relbow
rwrist
rfinger
marker
0
0.5
1
1.5
2
time (s)

# Eksperimentdesign

Hvordan gå frem for å:

- Studere personers opplevelse av en konsert?
- Studere en musikers bevegelser?

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- Studere personers opplevelse av en konsert?
- Studere en musikers bevegelser?
- Spørre dem?
  - Hva slags svar får du da?
- Observere og notere?
  - Er du deltaker eller obsevatør?
- Filme?
  - kvantitativ videoanalyse: lysforhold
  - personvern
- Ha konserten i en bevegelseslab?
  - Økologisk validitet
- Feste sensorer på personene?
- Andre forslag?

# Eksperimentdesign: steg for steg

1. Forskningsspørsmål
2. Forberedelser
   - Hvilke data trenger du for å svare på spørsmålet?
   - Hvordan skal du samle dataene?
     - Lage spørreskjema, finne musikkeksempler, ...
     - Identifiser potensielle problemer
     - Hvordan minimere potensielle feilkilder?
     - Større prosjekter: NSD
3. Gjør pilotforsøk
4. Gjør nødvendige endringer
5. Gjør forsøket
6. Analyser datamaterialet

# Forskningsspørsmål

Kan være litt vanskelig å formulere, men er et veldig godt hjelpemiddel.

## Eksempel 1: Tema, men ikke forskningsspørsmål

- Tema: "Bevegelser black metal musikk".
- Hvem sine bevegelser? Hvilke bevegelser? I hvilken sammenheng?
- Hvor begynner man en slik oppgave?

## Eksempel 2: Samme tema med et forskningsspørsmål

- Spørsmål/problemstilling: "Hvilken sammenheng er det mellom headbanging og musikalske parametre hos black metal gitarister?"
- Se på et utvalg av gitarister, eller snevre inn oppgaven enda mer til å se på ett band eller én person.
- Hva kan undersøkes? (underproblemstilling)
  - Frekvensen: Hvor fort beveger hodet seg?
  - Hvor store bevegelser gjøres?
  - Endres noen av disse med tempo / intensitet i musikken?
  - Er det forskjell med samme utøver fra gang til gang?
  - Er det forskjell mellom ulike utøvere?

# Hva slags data trenger vi?

- Antall personer?
  - Skal jeg prøve å si noe generelt om metal-gitarister? Hvis *ja* trenger jeg flere personer. (I semesteroppgaver er det ok med ganske smale problemstillinger, så f.eks. å undersøke bare 1 person kan være ok).
- Hva slags data trenger jeg for å svare på spørsmålet?
  - Kanskje det holder å gå på en konsert og gjøre notater?
  - Video fra youtube?
  - Eget kontrollert videoopptak?
  - Markørbasert infrarød motion capture?
  - Burde jeg ha et spørreskjema for å vite litt om forsøkspersonen?
- Infrarød motion capture. Hvilke problemer kan jeg støte på?
  - Hår som blokkerer for markører.
  - Bruke mocap-hatt? — Setter jeg i så fall utøverne i en ukomfortabel situasjon? Forberede dem på det.
  - Hatten kan dessuten falle av.
- Økologisk validitet VS kontollabilitet.
  - La gitaristene spille sine egne sanger, eller gi dem én bestemt sang de skal spille for å kunne sammenlikne?
  - La alle gitaristene headbange til den samme sangen uten å spille?

## Spørreskjema

- Samle kun relevant data. F.eks:
  - Spørsmål som er direkte knyttet til problemstillingen
  - Informasjon som kan brukes til å vise at du har et representativt utvalg av folk: Kjønn, aldersfordeling
  - Tilbakemelding på forsøket
- Hvis du gjør videoopptak, spør om det er ok at du viser det til andre. Legges det på internett?

## Pilotforsøk

- Ta noen få personer gjennom et testforsøk
- Hva lærer du? Er det noen problemer du har oversett?
- Gjør nødvendige endringer, f.eks. i instruksjonen du gir til deltakerne.

# Oppsummering

- Bevegelssporing / Motion Capture: Mange typer. Fordeler / Ulemper
- Digital representasjon av en bevegelse
- Markør, Rigid object, Kinematisk kjede, Biomekanisk modell
- Feil i data: Gaps, støy, drift.
- Visualisering av data: Godt hjelpemiddel for å tolke dataene
- Eksperimentdesign: Start med et forskningsspørsmål
- Velg metode ut ifra behov
- Analyse: Tema for de to neste forelesningene (kvalitativ / kvantitativ)

# Diverse info:

- Oppgave 2: Ligger på nett
- Verktøy: VideoAnalysis. Sofia Dahl går gjennom programmet på forelesningen 12. mars.
  - Ta med laptop med programmet installert:
  - http://fourms.uio.no/downloads/software/VideoAnalysis
  - PC-brukere må også installere quicktime
- 16-18 mars: Opptak i laben (til oppgave 3)
- 12 mars: NM i stillstand for de som har lyst