

# Measuring strain in three dimensions

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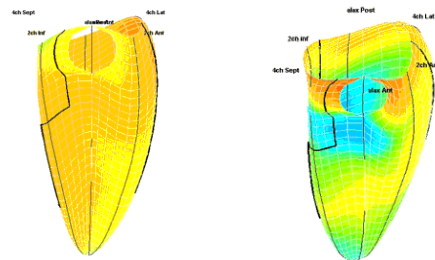
<http://folk.ntnu.no/stoylen/lectures/>  
<http://folk.ntnu.no/stoylen/strainrate/>

# What does it mean to measure strain in 3D?

## 3D reconstruction:

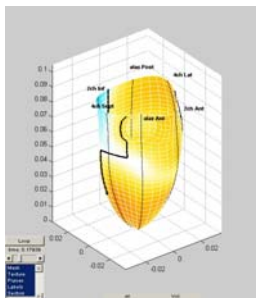


## Strain on a 3D surface:

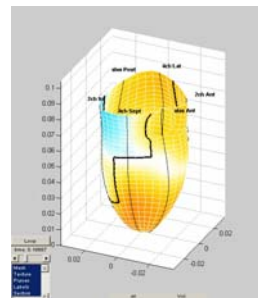


E. Sagberg

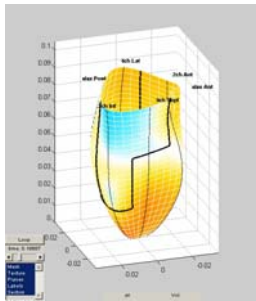
## Display



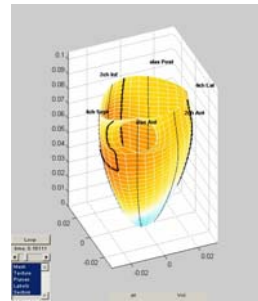
## Display



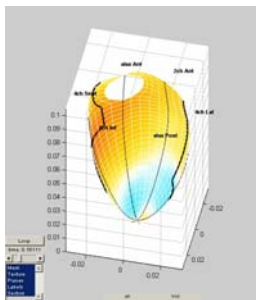
## Display



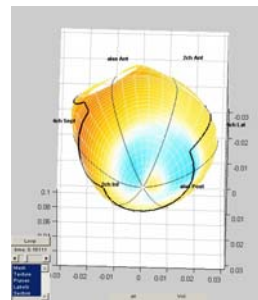
## Display



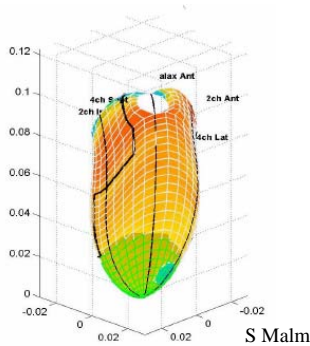
## Display



## Display



## Area representation

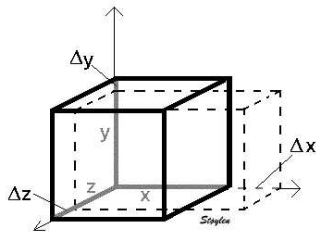


## 3D reconstruction:

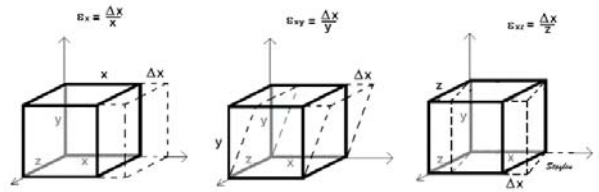
- 3D distribution of one dimensional (longitudinal) strain:

- Display
- Area representation
- Not true 3D strain.

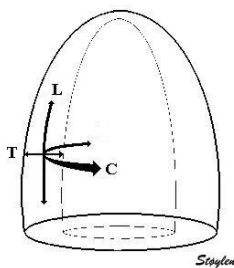
## Strain in three dimensions:



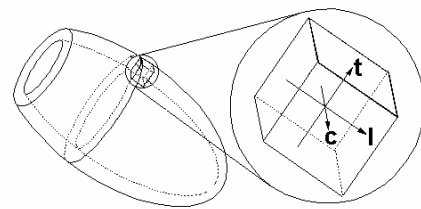
## Strain in three dimensions:



## In the left ventricle:



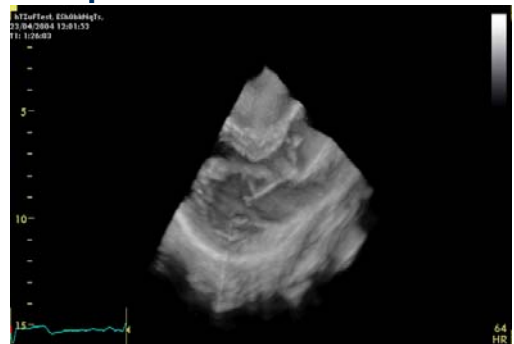
## In the left ventricle:



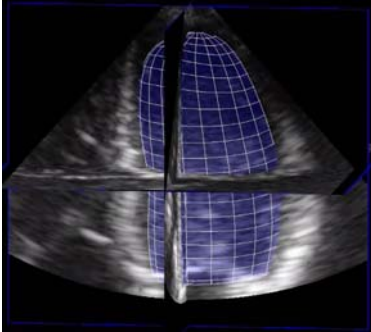
## How to measure strain in three dimensions?

- 3D acquisition – speckle tracking
  - Limited frame rate
  - Limited line density
- Geometrical models
  - Based on geometrical assumptions

## 3D acquisition:

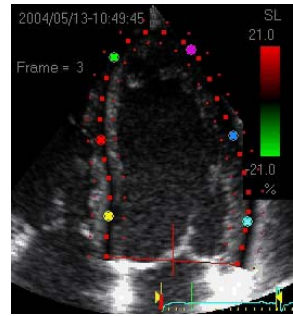


### 3D acquisition:

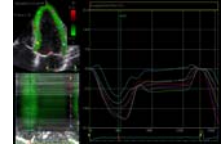


F Orderud

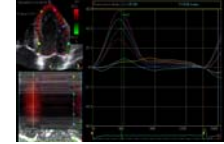
### Experience from 2D strain:



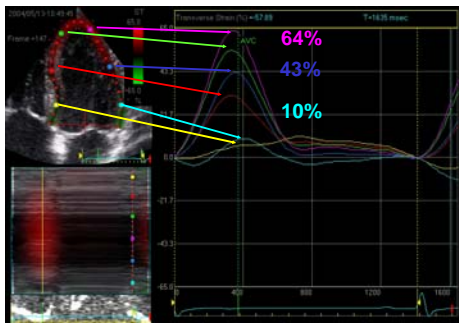
Longitudinal



Transmural



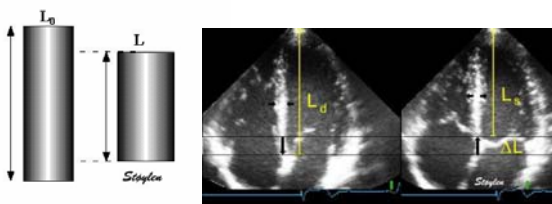
### Lateral resolution – transmural strain:



### 3D acquisition:

- Present line density (and frame rate) too low.
- Can be used for developmental purposes.
- Major improvement in spatial resolution necessary for useful results

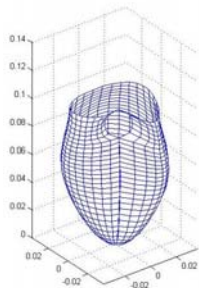
### Incompressibility:



### 3D reconstruction:

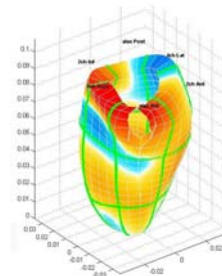


## Deformation in 3D



$$(\epsilon_x + 1) (\epsilon_y + 1) (\epsilon_z + 1)$$

## Wall thickness

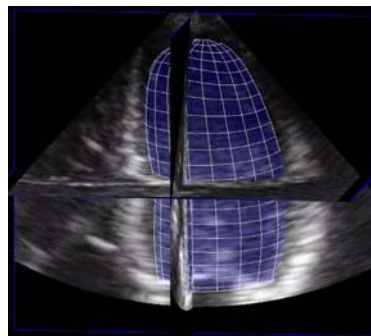


Redundant information

## Wall thickening:



## Combined methods:



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## Conclusions:

- Strain in 3D is possible by using geometrical modelling and incompressibility assumptions
- Strain in 3D recordings is probably dependent on a breakthrough in technology, allowing for higher line density.
- A combination may be feasible in the near future