

# A Low-cost Multitouch Spherical Display : Hardware and Software Design

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Thomas Crespel, Patrick Reuter, Xavier Granier

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05/24/2017



**1. Context**

2. Hardware

3. Software

4. Results & Conclusion

# Low-cost multitouch spherical display

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- Opaque globe displaying interactive data
- All-around viewers



source : *Global Imagination*

## Applications :

- Teaching
- Collaborative work
- Communication
- ...

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# Low-cost multitouch spherical display

- Costly existing products
- Spread the use

- Opaque globe displaying interactive data
- All-around viewers

- Intuitive interaction



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- Teaching
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# Related work

## Low-cost multitouch spherical display

Projection-based solutions

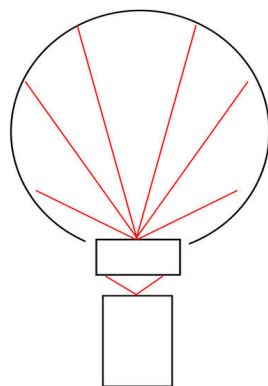
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## Low-cost multitouch spherical display

### Projection-based solutions

#### Global Imagination

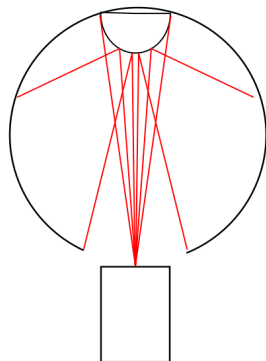
[globalimagination.com](http://globalimagination.com)



- DLP projector
- Custom fisheye lens

#### ArcScience

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- DLP projector
- Custom hemispherical mirror
- Casts shadows on the north pole



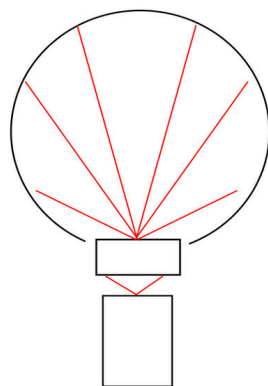
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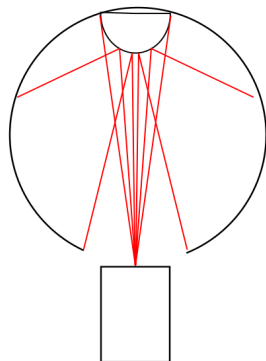
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- Large displays
- Good quality

- Patented optical elements
- Expensive
- Not multitouch

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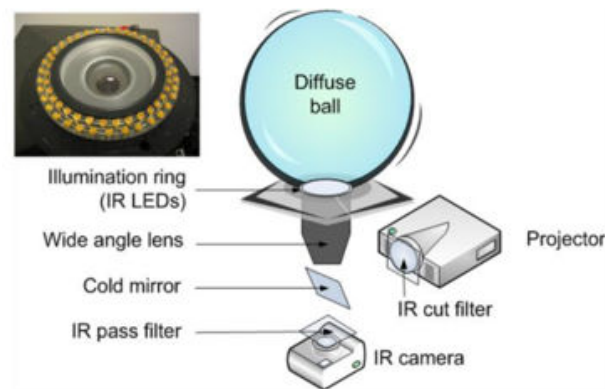
Low-cost multitouch spherical display

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## Low-cost multitouch spherical display

### Microsoft Research

[Benko, 2008]



- Add multitouch capabilities to Global Imagination's product
- Cold mirror + Infrared finger tracking

### Pufferfish

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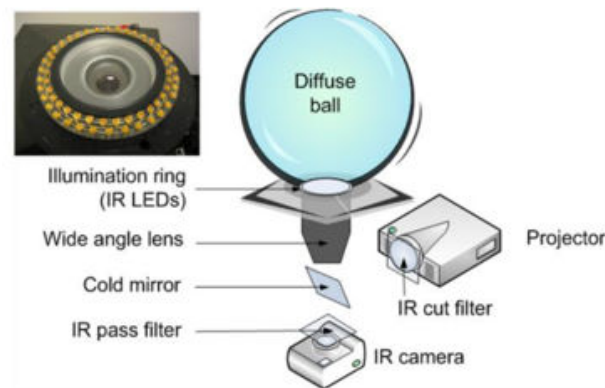
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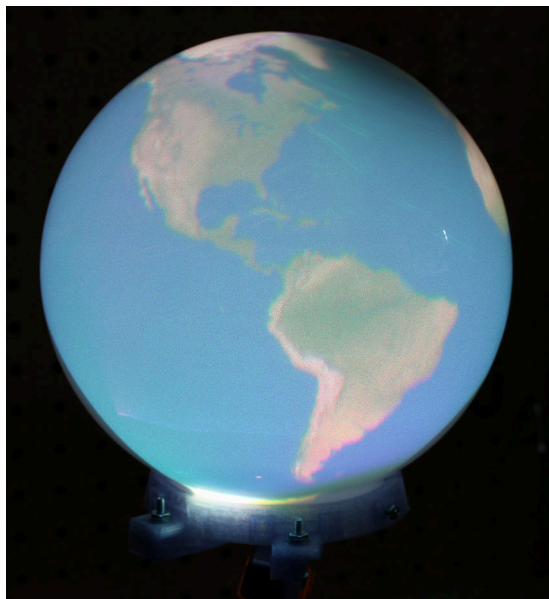
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## Low-cost multitouch spherical display

### “Do-it-yourself” spherical display

<http://eclecti.cc/computergraphics/snow-globe-part-one-cheap-diy-spherical-projection>



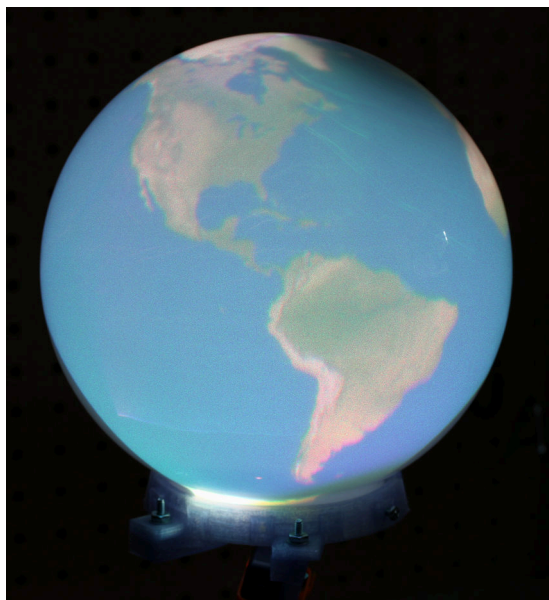
- « Focus-Free » projector
- \$30 fisheye lens
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➤ « Focus-Free » projector

➤ \$30 fisheye lens

➤ 3D printed parts

- Cheaper than other solutions
- Easily reproducible

- Does not cover the entire sphere
- Not multitouch

# Our solution

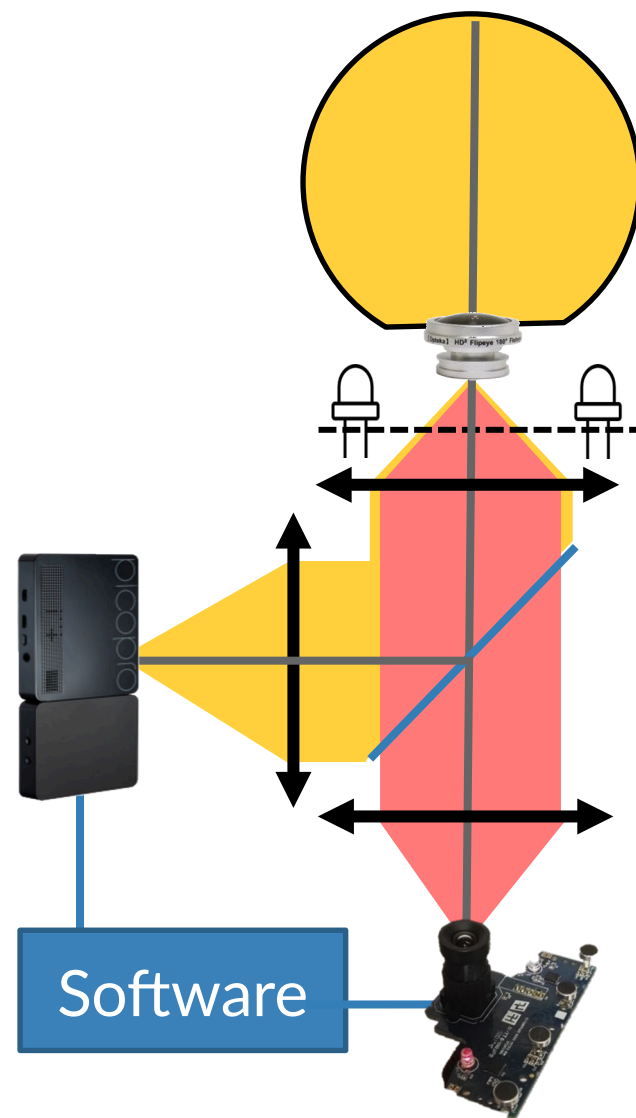
## Low-cost multitouch spherical display

### HARDWARE

- Focus-free projector
- Off-the-shelf optical components
- Cold mirror
- Infrared finger tracking
- 3D printed parts

### SOFTWARE

- Projection
- Interaction
- Compensate the use of cheap optics
- Calibration



1. Context

**2. Hardware**

3. Software

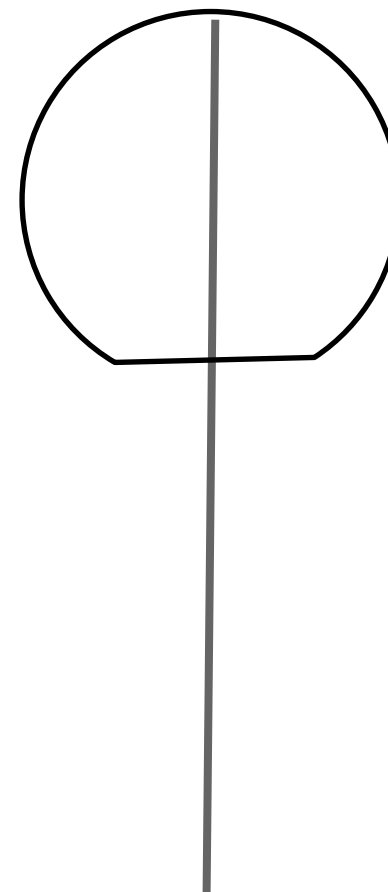
4. Results & Conclusion



# Hardware – Rear projection

## Frosted glass sphere

- 24cm diameter
- Rear projection screen



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## Fisheye lens : Opteka x0.2

- Designed for photography
- Magnification x5
- $\pm 90^\circ$  output  $\rightarrow \pm 18^\circ$  input



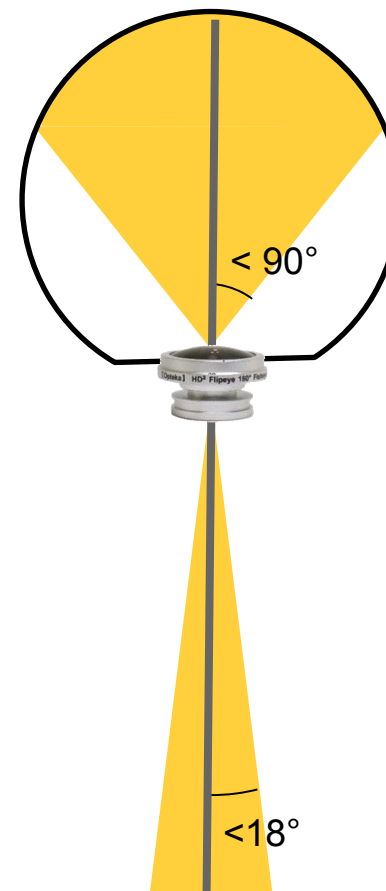
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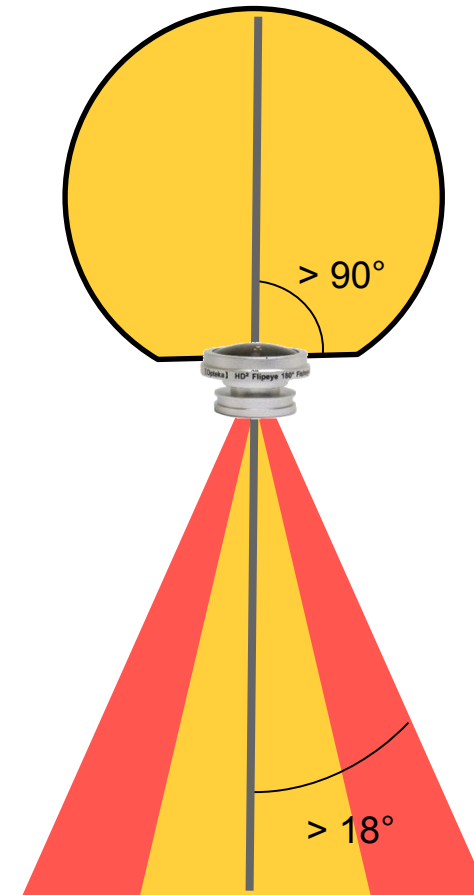
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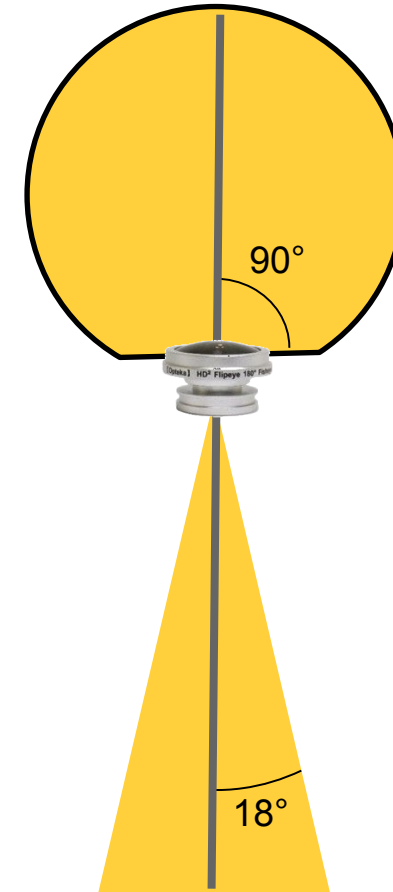
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## Laser Beam-Steering Projector : Celluon PicoPro

- “Focus-free”
- Spatiotemporal scanning of R, G, B low diverging laser beams
- Specs : Brightness : 30 lumens  
Resolution : 1920x720p  
Field of view :  $\pm 11^\circ$  vertically  
 $\pm 22^\circ$

horizontally



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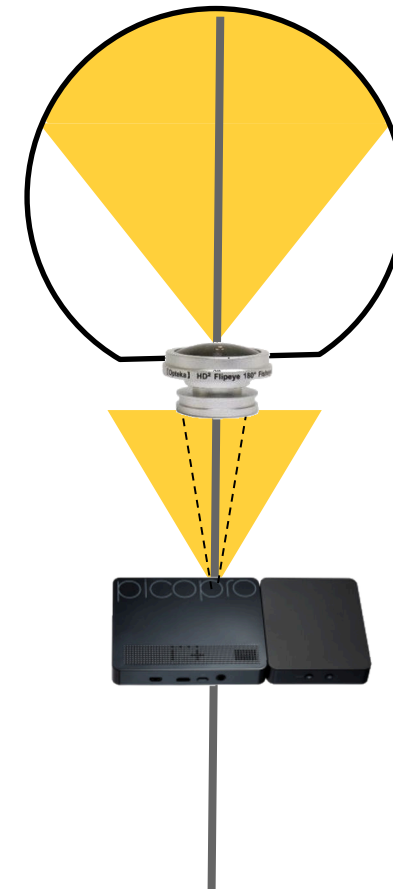
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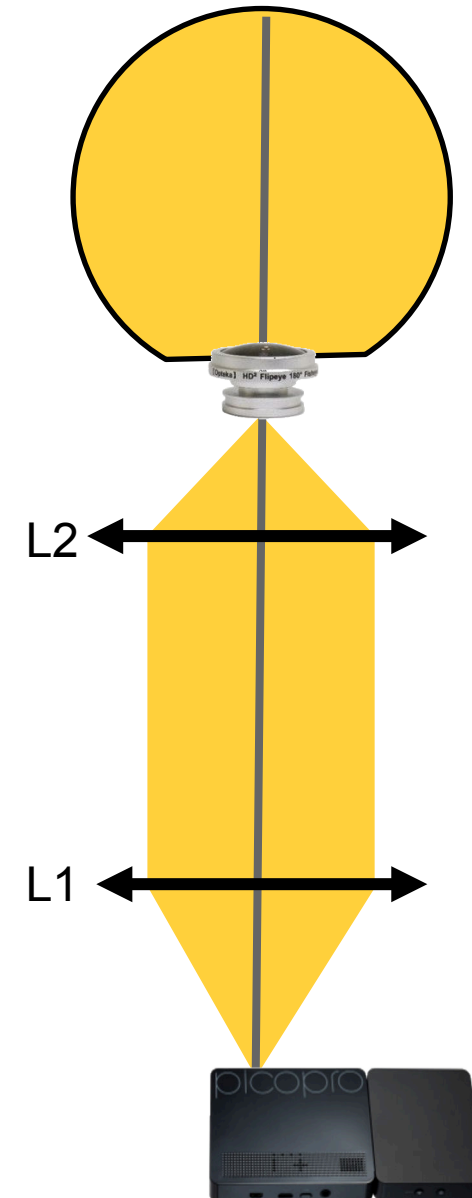


Vertically : limited by the FOV  
Horizontally : limited by the fisheye aperture

# Hardware - Imaging optical system

Goals :

- Add optical distance between projector and fisheye lens
- Adapt the input angle on the fisheye
- Maintain a sharp image





# Hardware - Imaging optical system

## Goals :

- Add optical distance between projector and fisheye lens
- Adapt the input angle on the fisheye
- Maintain a sharp image

- The envelope is focused with a correct angle
- The scanning beam has correct divergence

- The envelope is collimated
- The scanning laser beam is focused

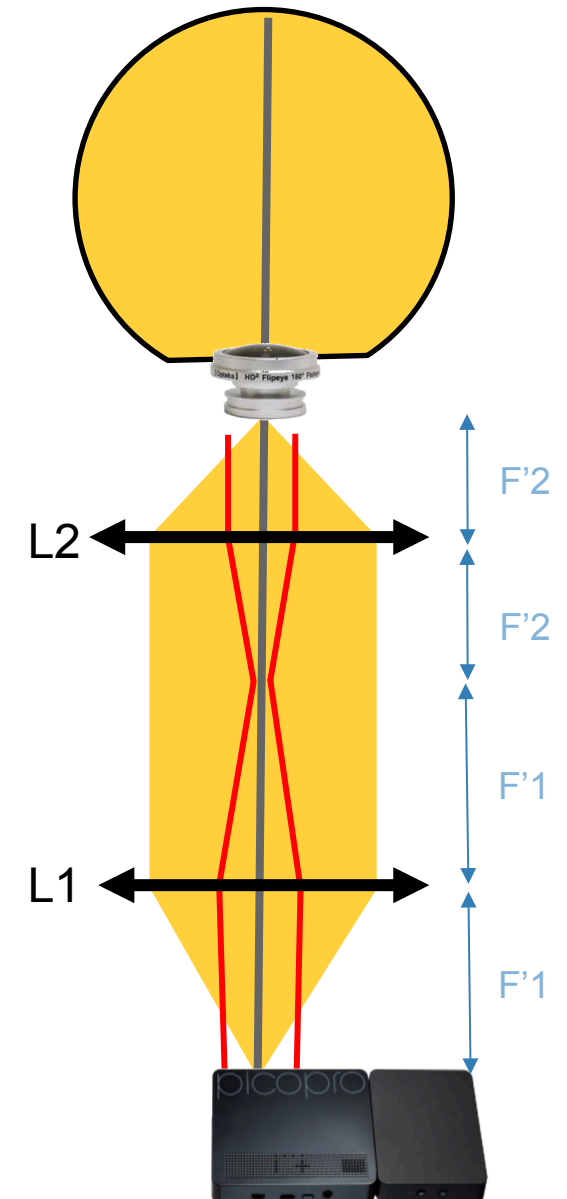
- The vertical FOV is collected by L1

lost pixels



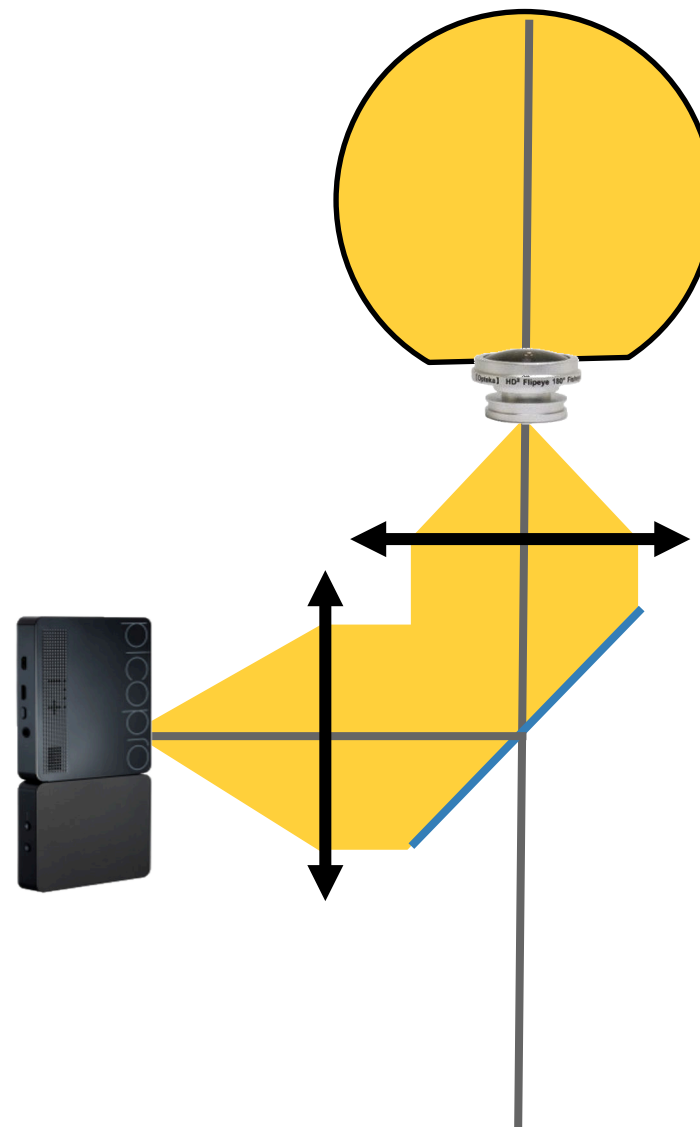
transmitted pixels

- The scanning laser beam is slightly diverging



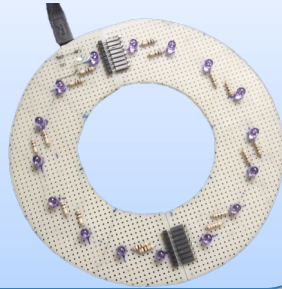
# Hardware - Optical tracking

**45° Cold mirror**  
Reflects the visible light, transparent for infrared

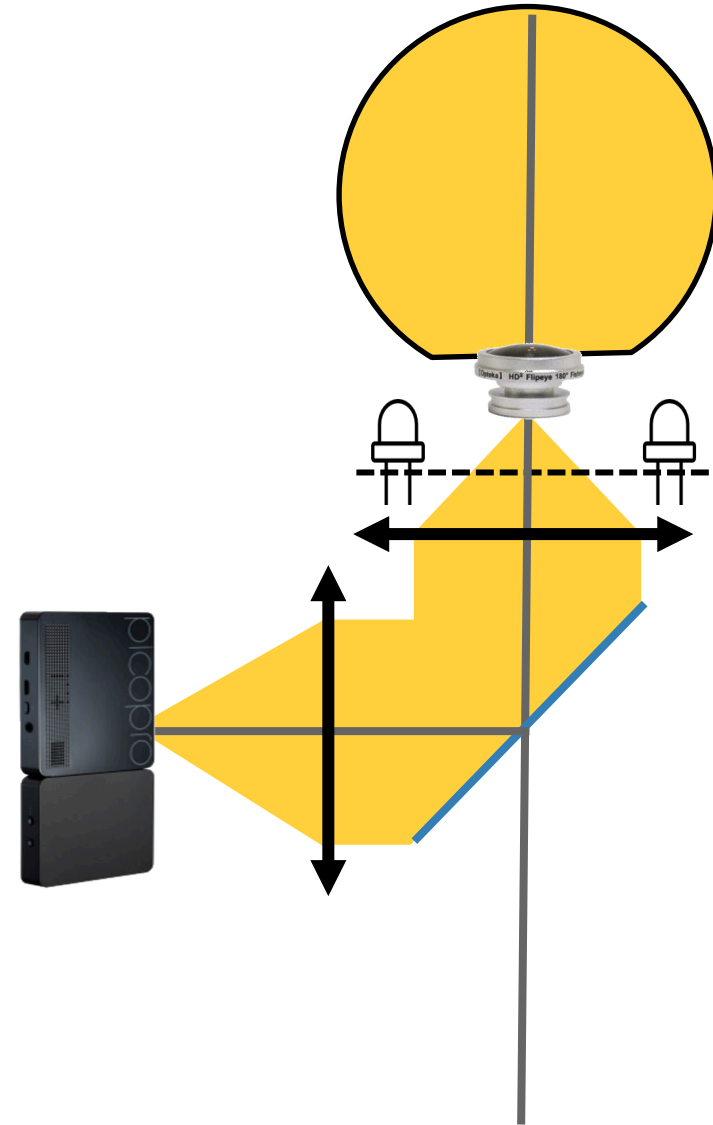


# Hardware - Optical tracking

Infrared LEDs ring @880nm

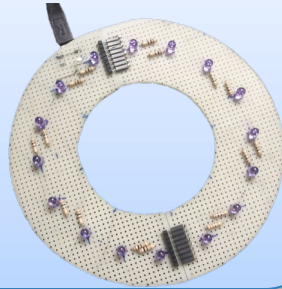


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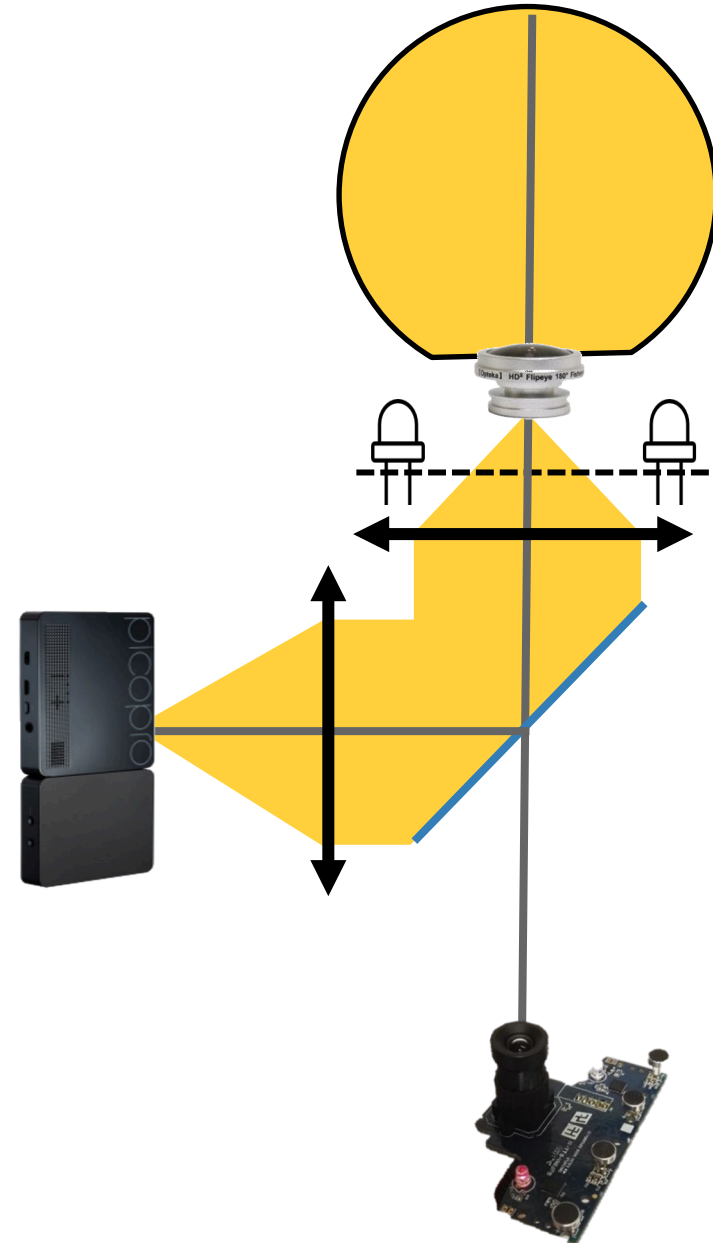


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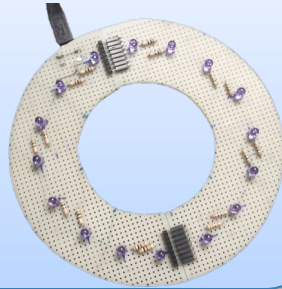
Modified PSeeye camera

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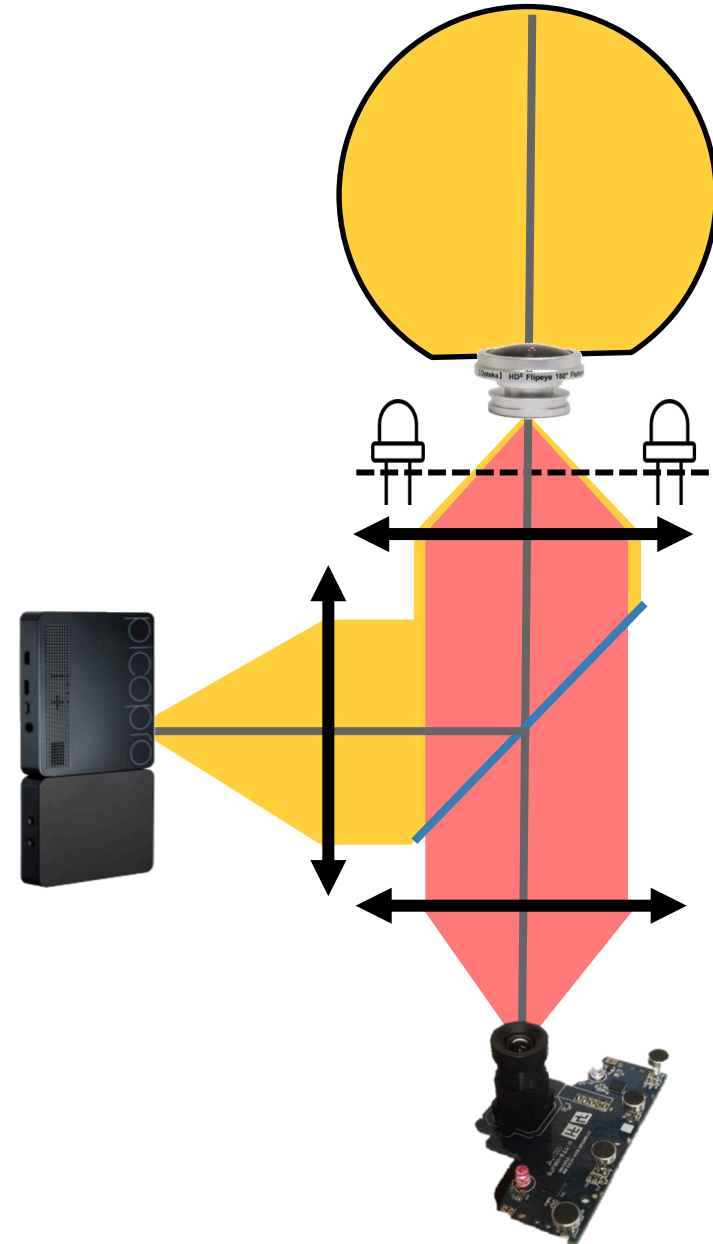


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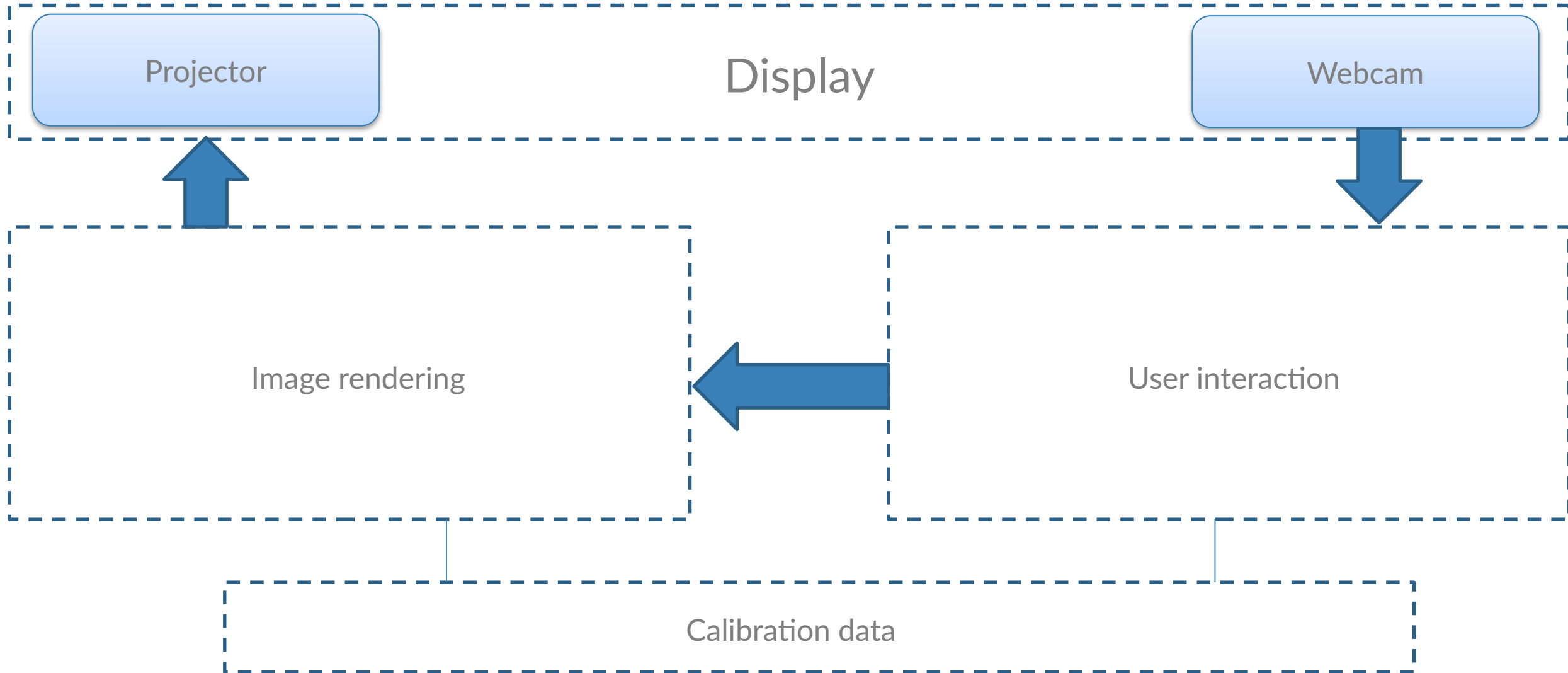
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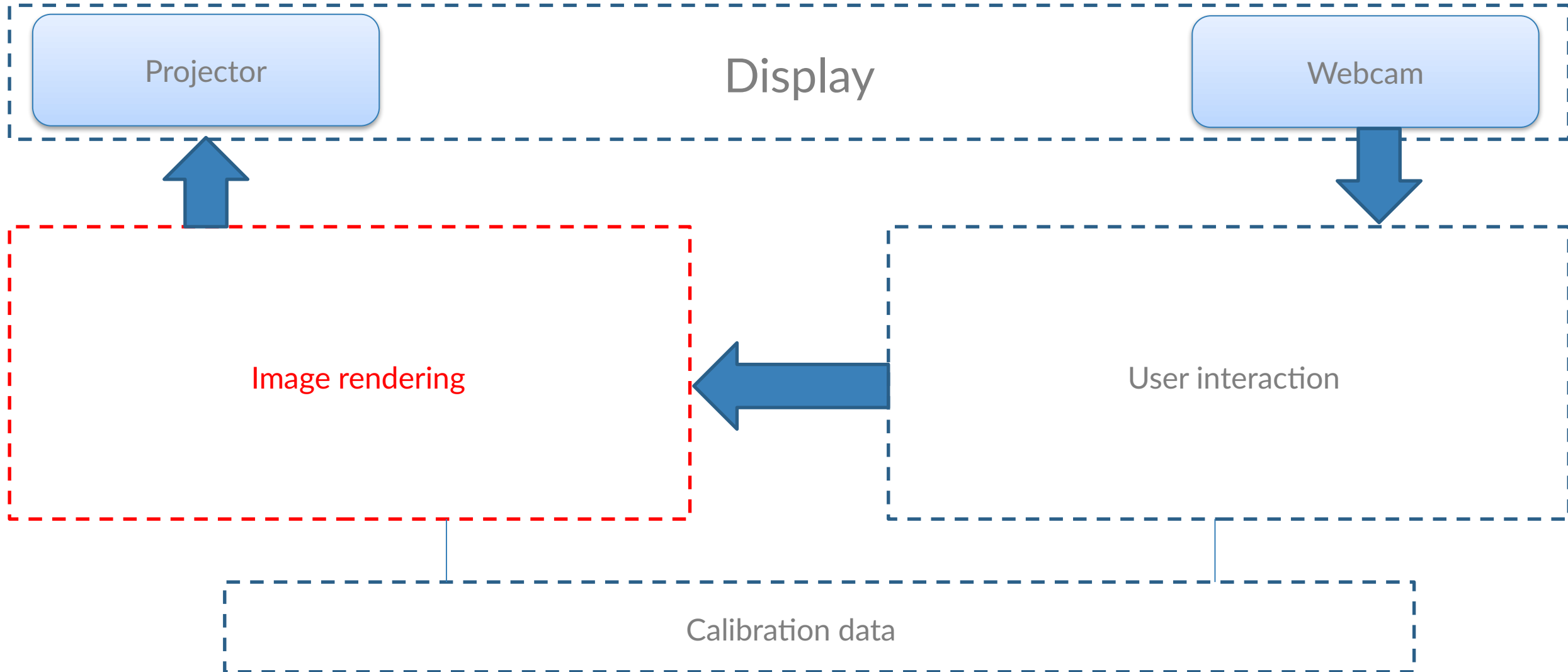


1. Context
2. Hardware
- 3. Software**
4. Results & Conclusion

# Software - Overview

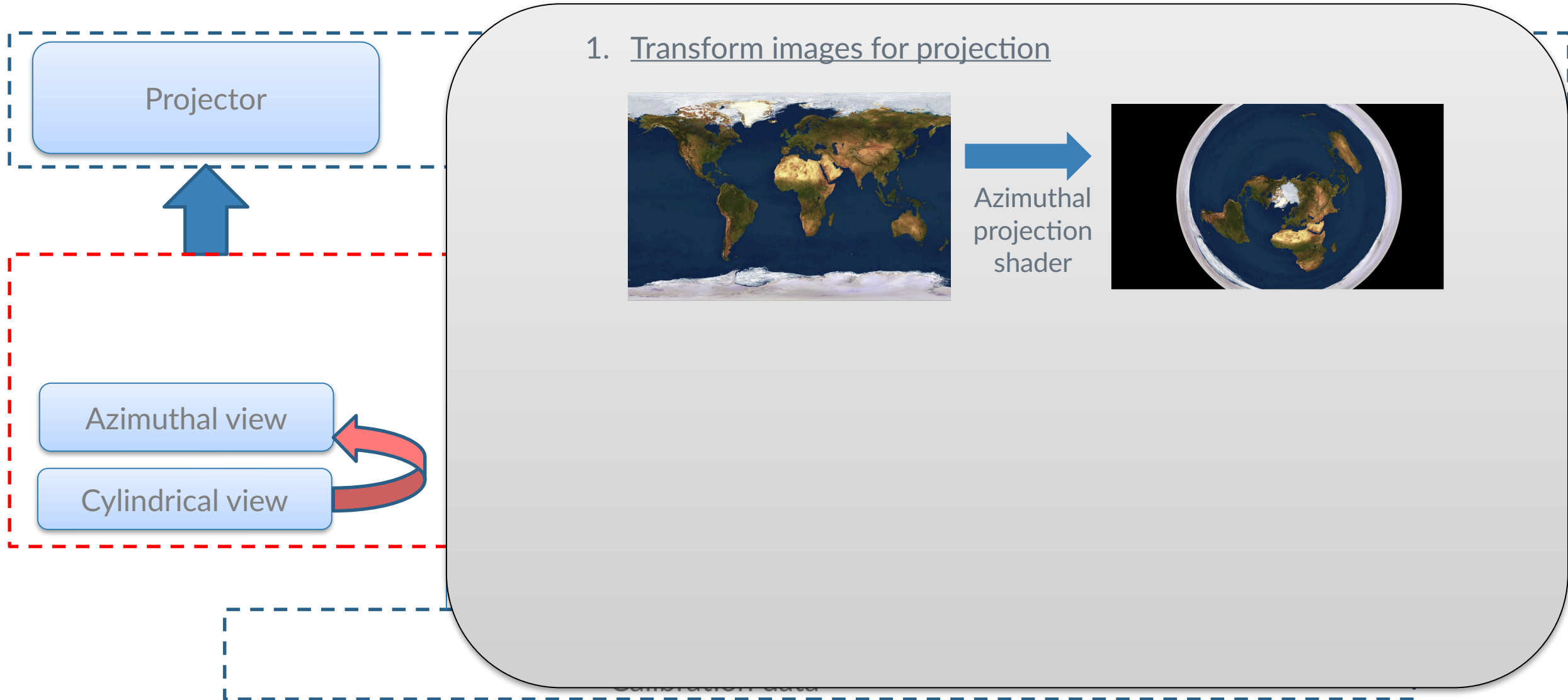


# Software - Overview

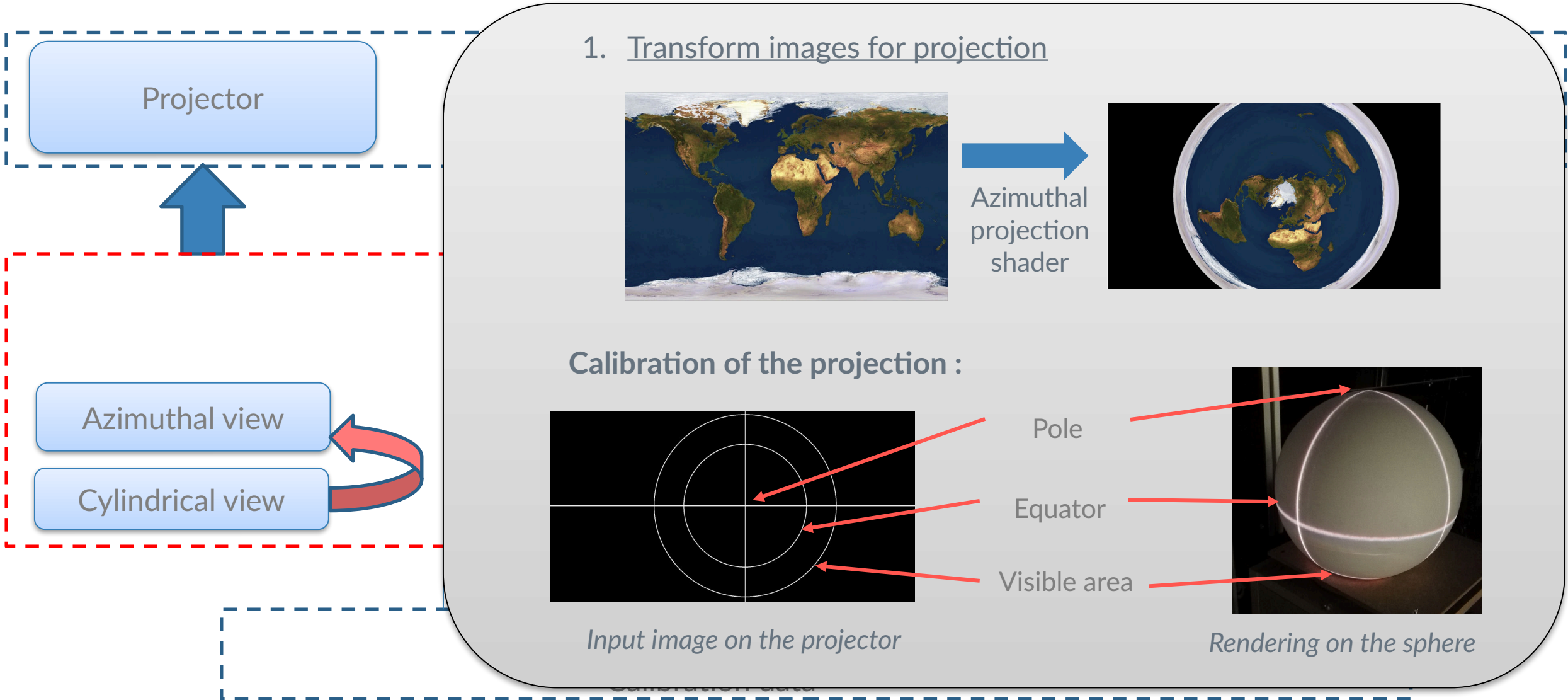




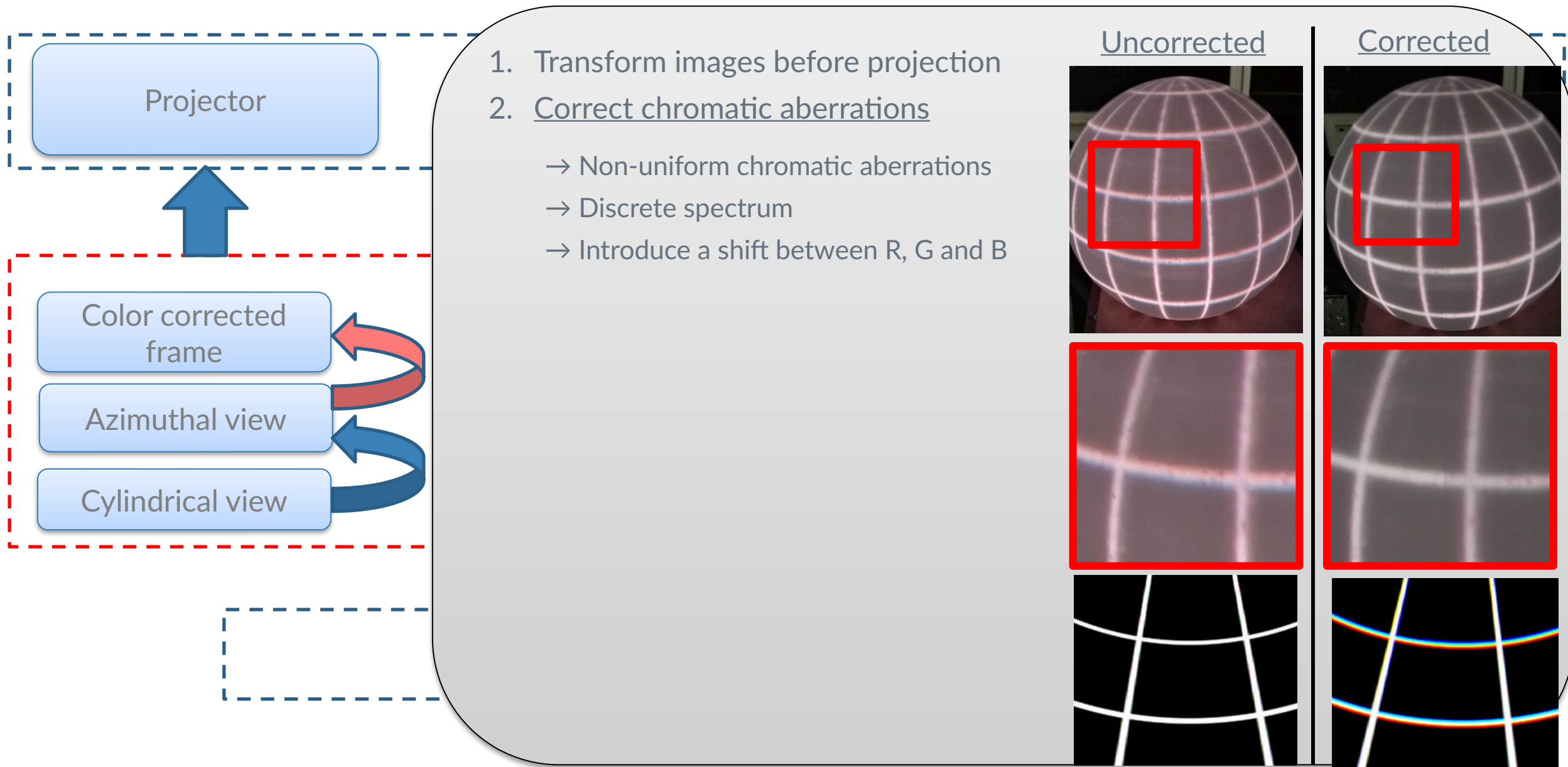
# Software – Image rendering



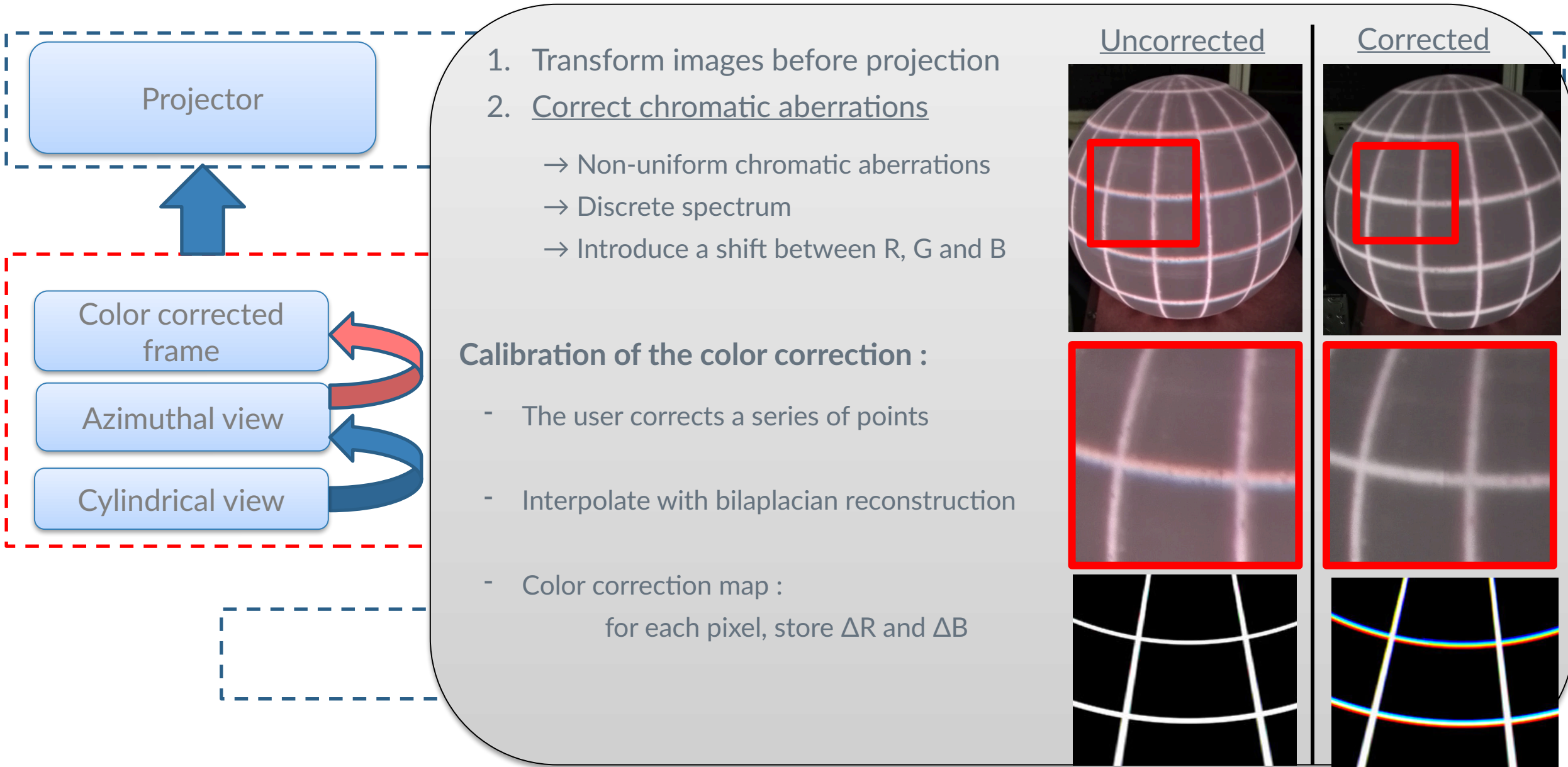
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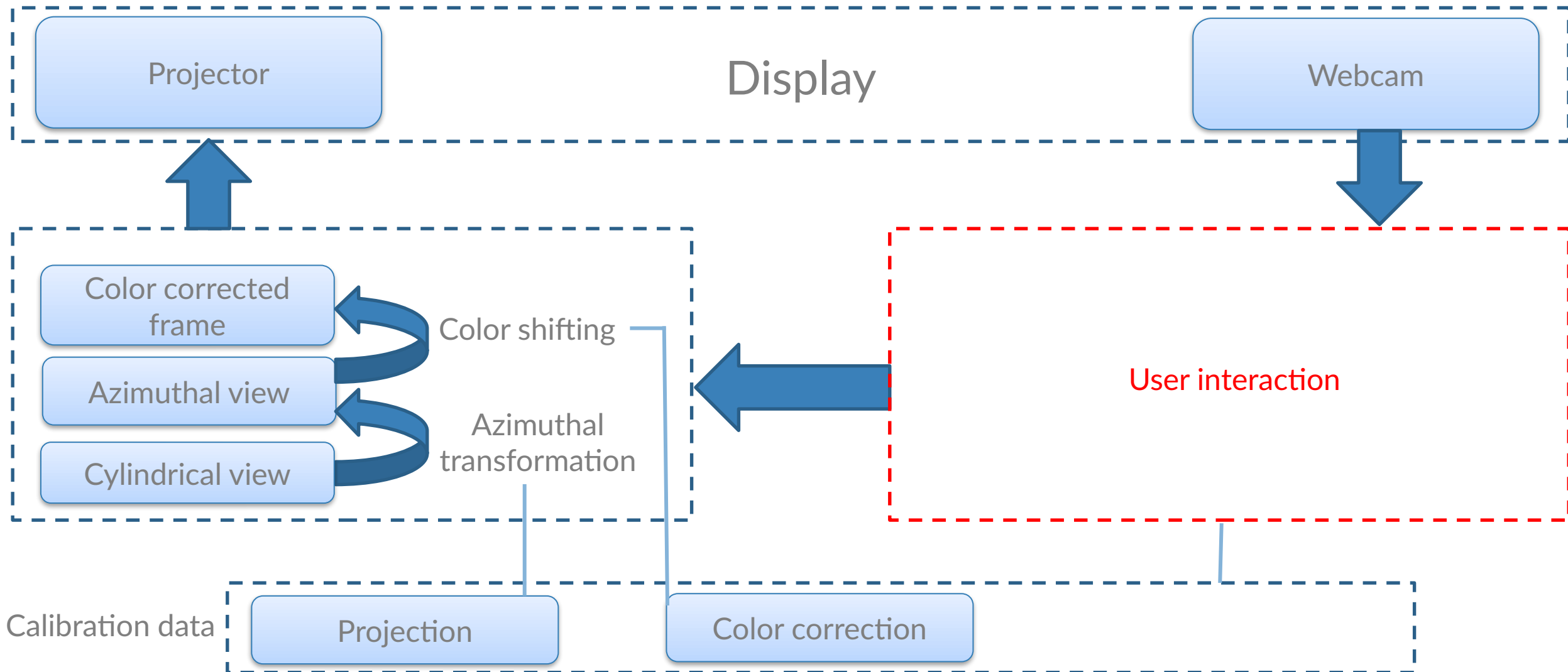
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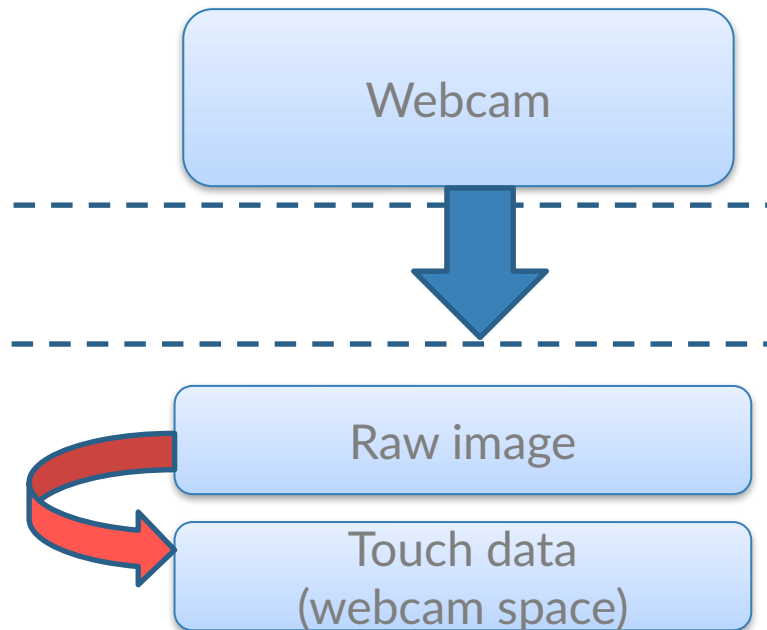
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# Software – User interaction

## 1. Track the fingers

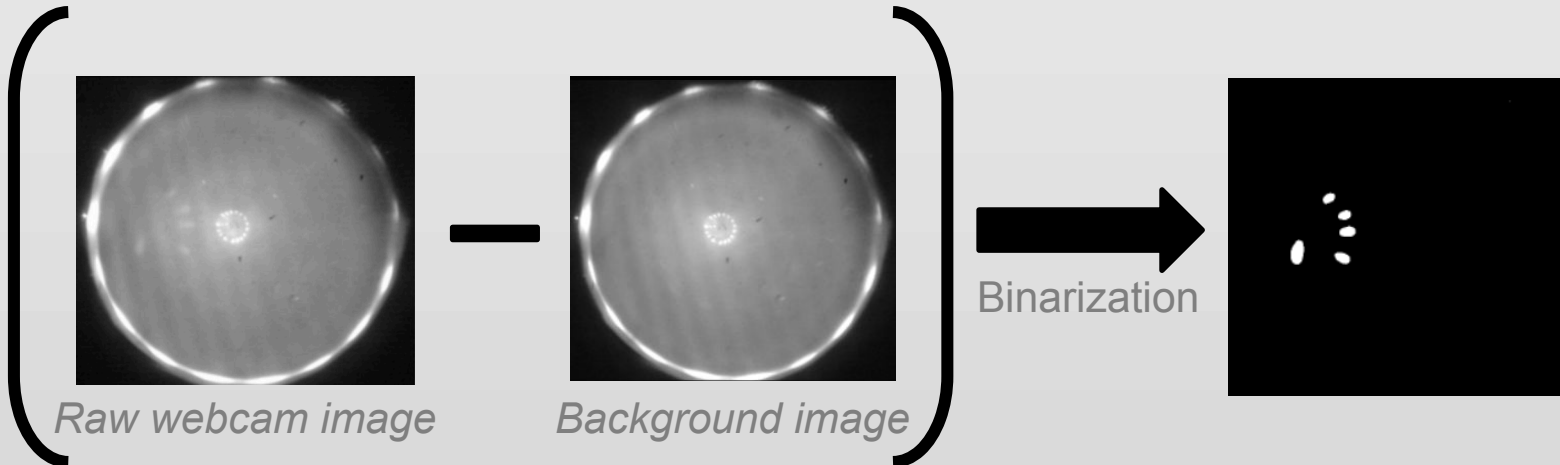
→ Computer vision algorithms



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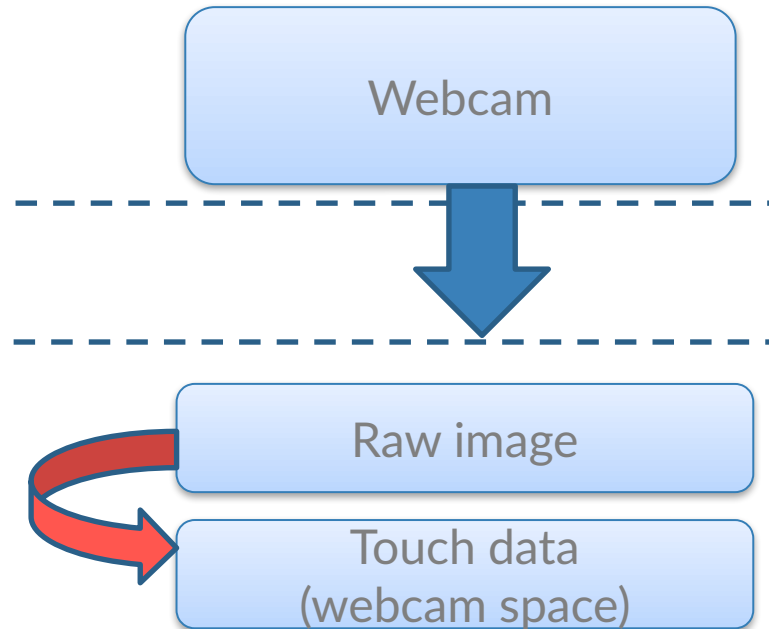
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**Parameters :** Smoothing, noise removing, amplification, binarization threshold, touch size....

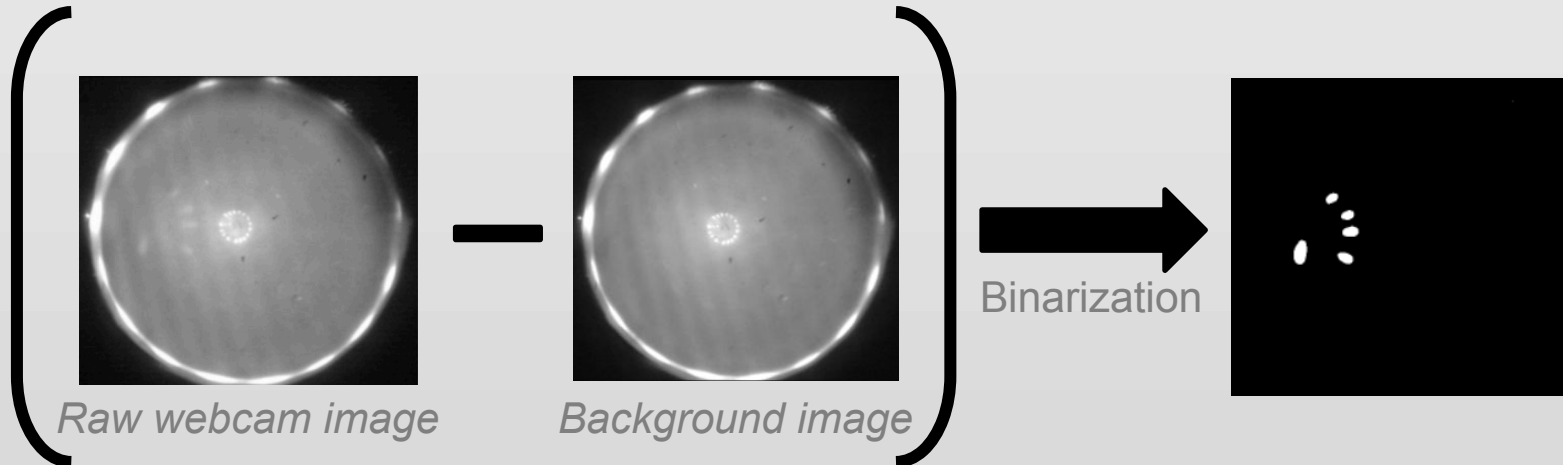
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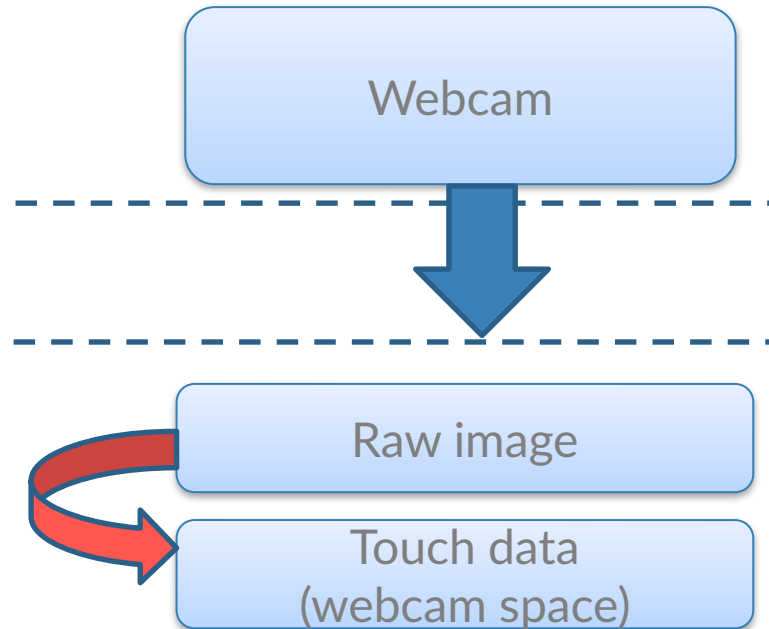
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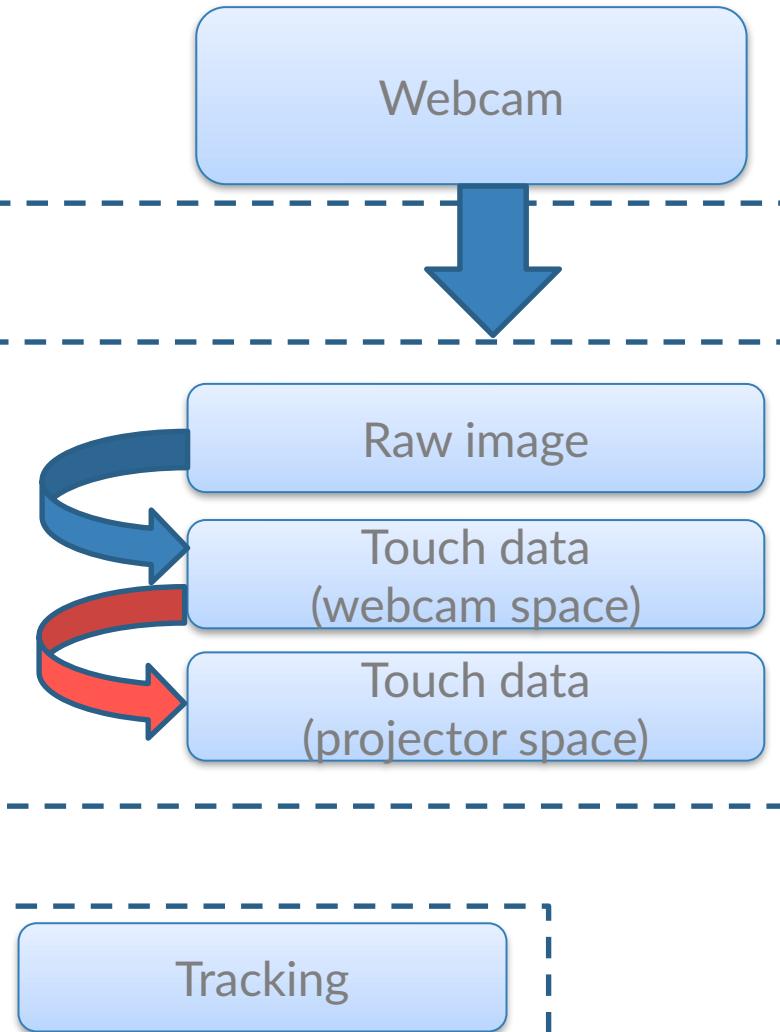
**In webcam space !**





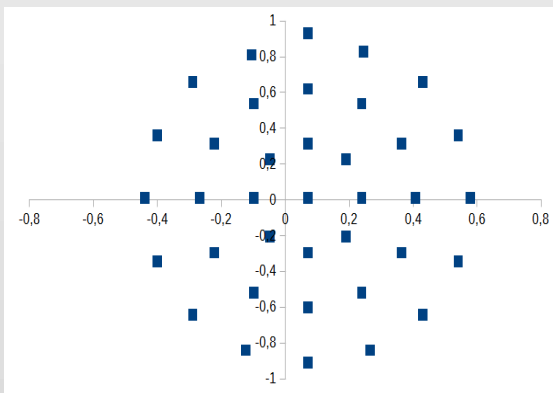
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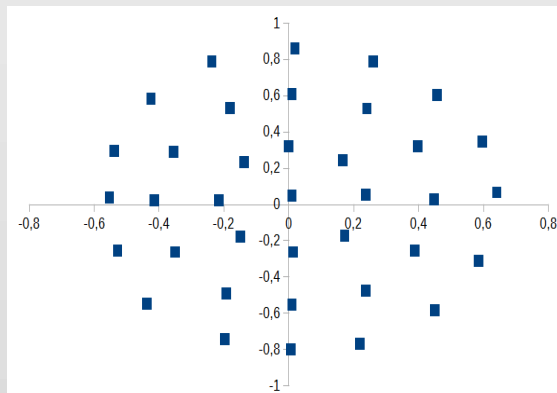


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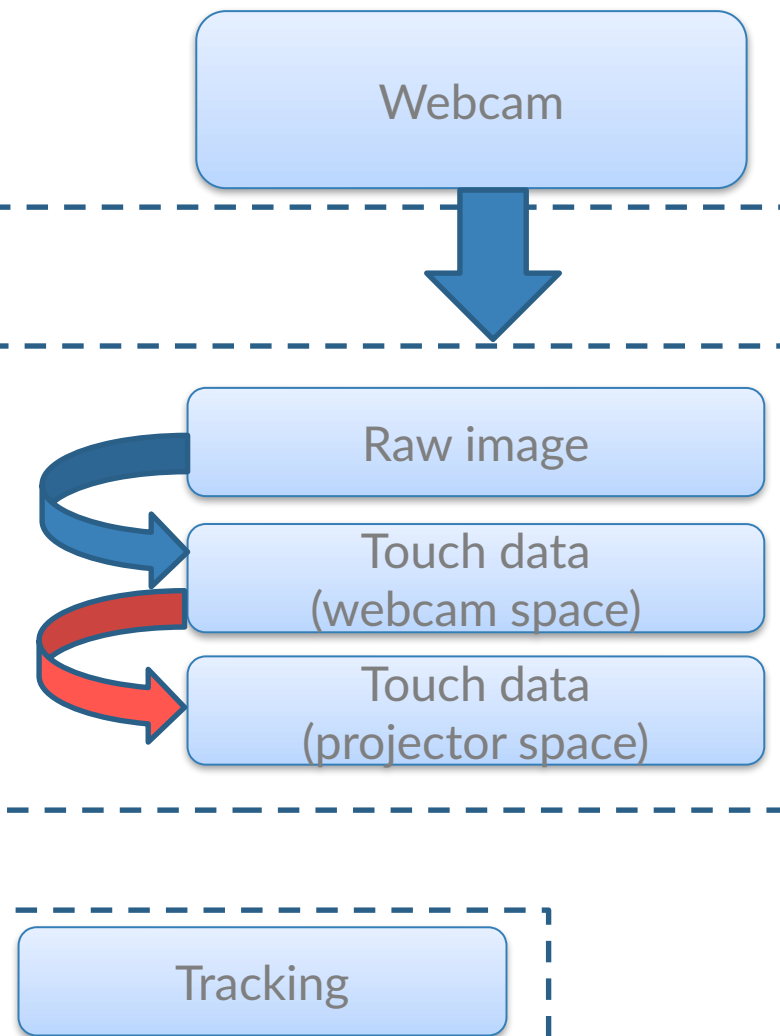
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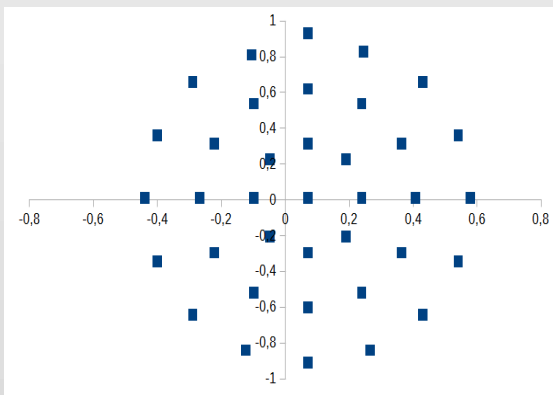


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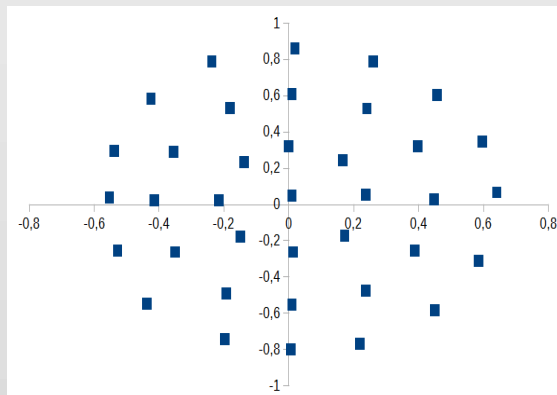


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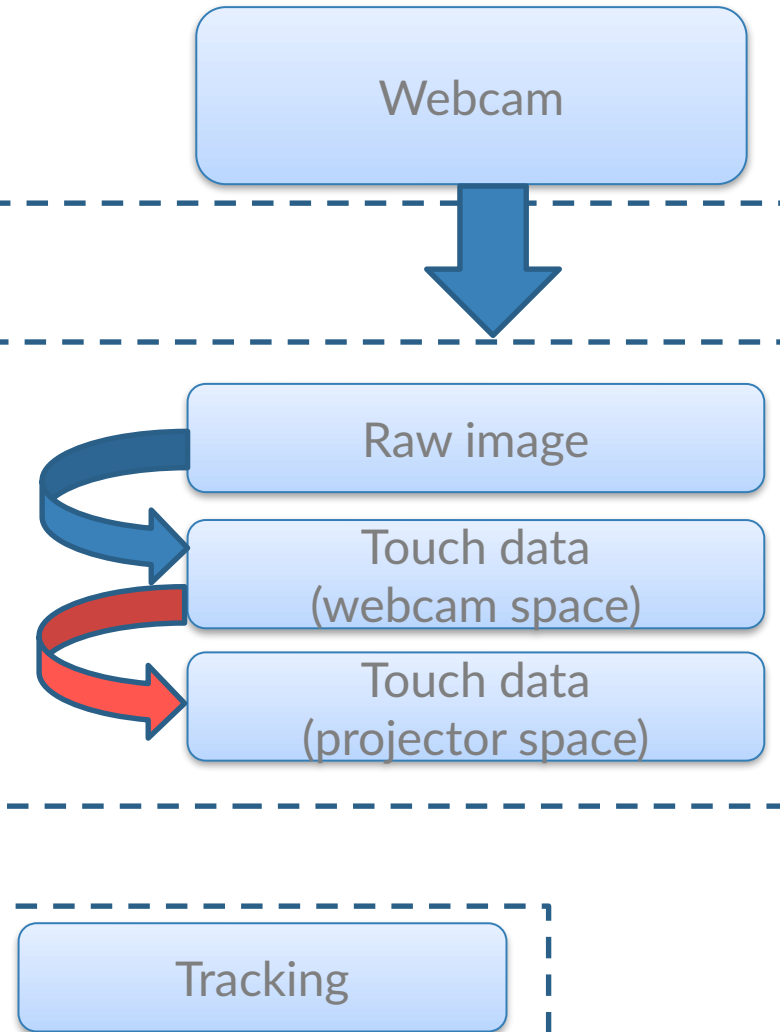


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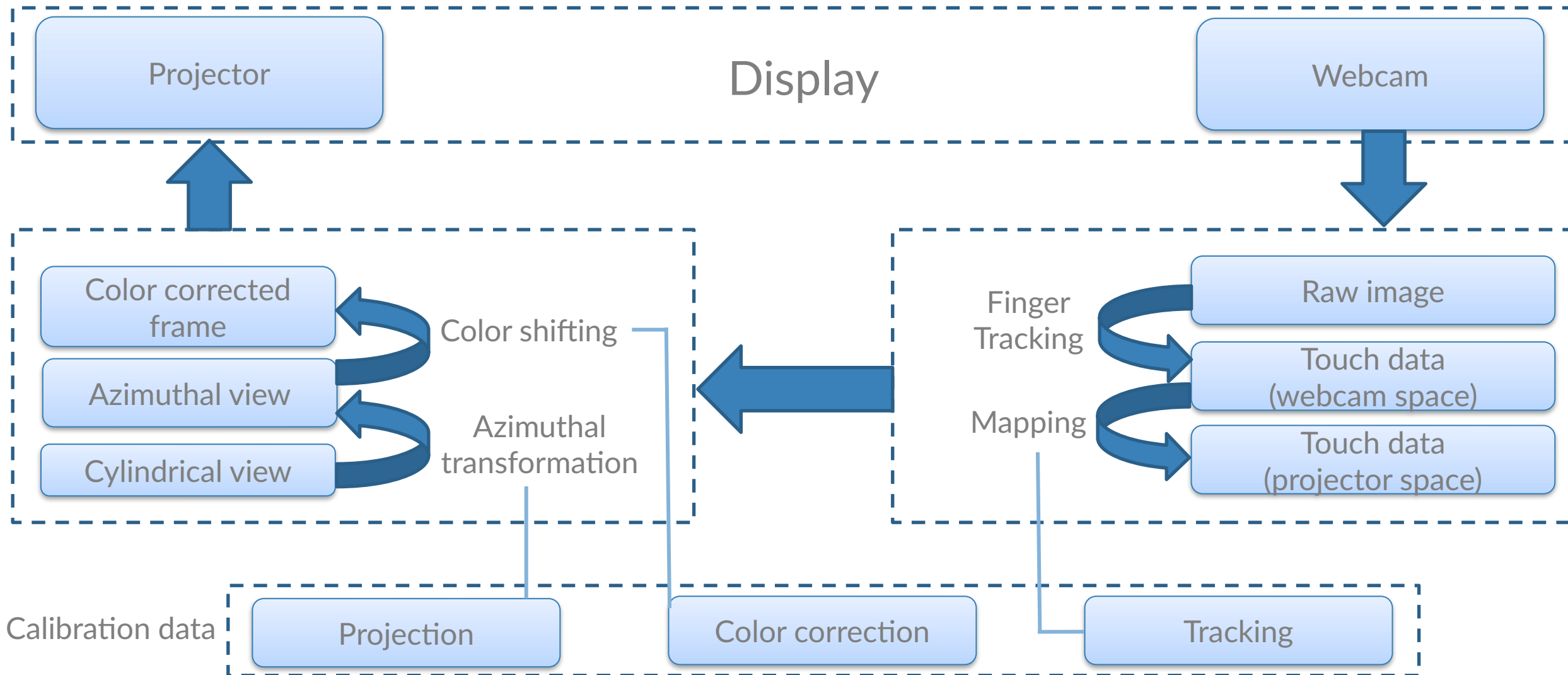
## Calibration of the finger tracking:

Find a mapping  $F : (X_{\text{webcam}}, Y_{\text{webcam}}) \rightarrow (X_{\text{projector}}, Y_{\text{projector}})$

- The user touches a series of projected points
- Bilaplacian reconstruction



# Software - Overview



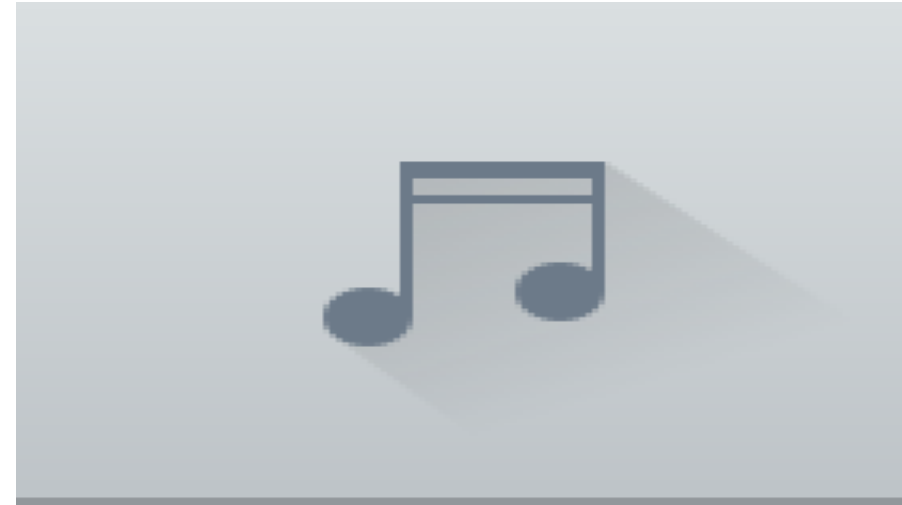
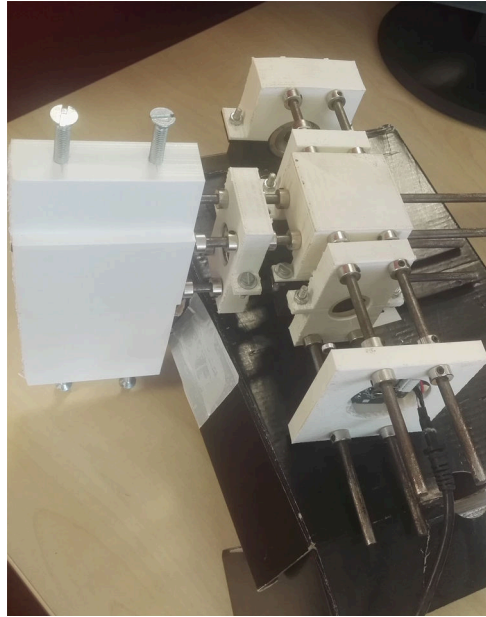
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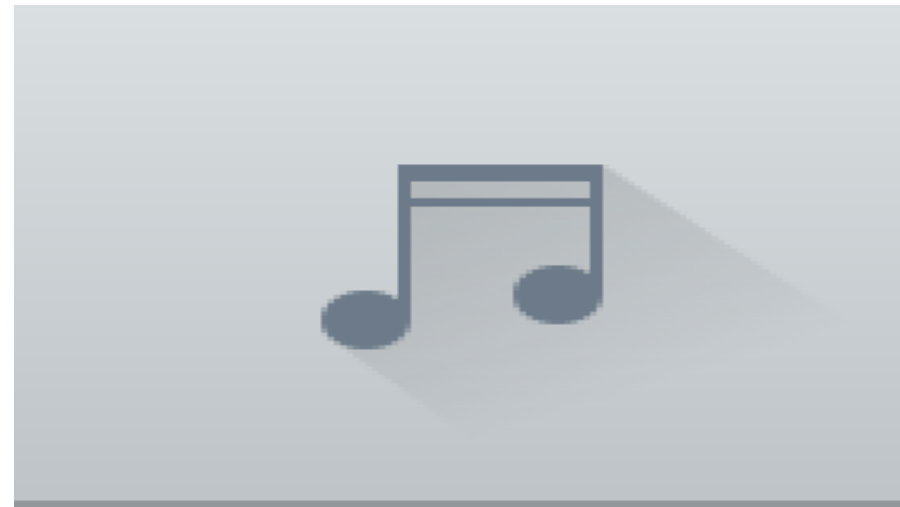
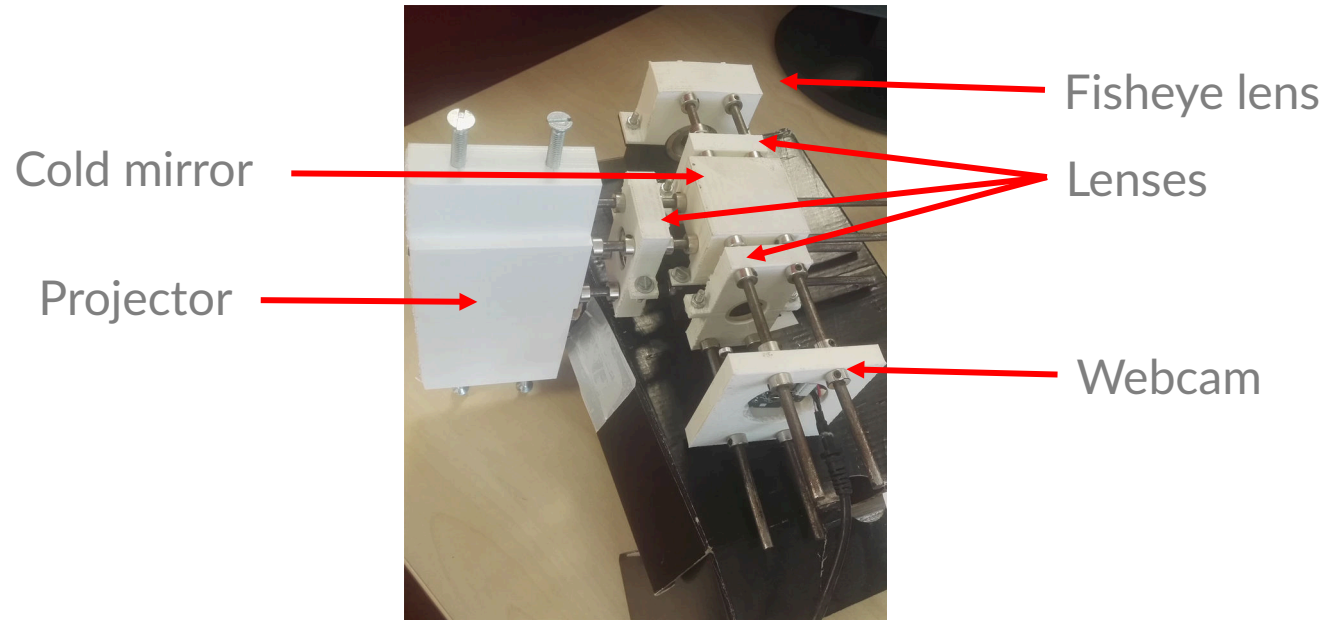
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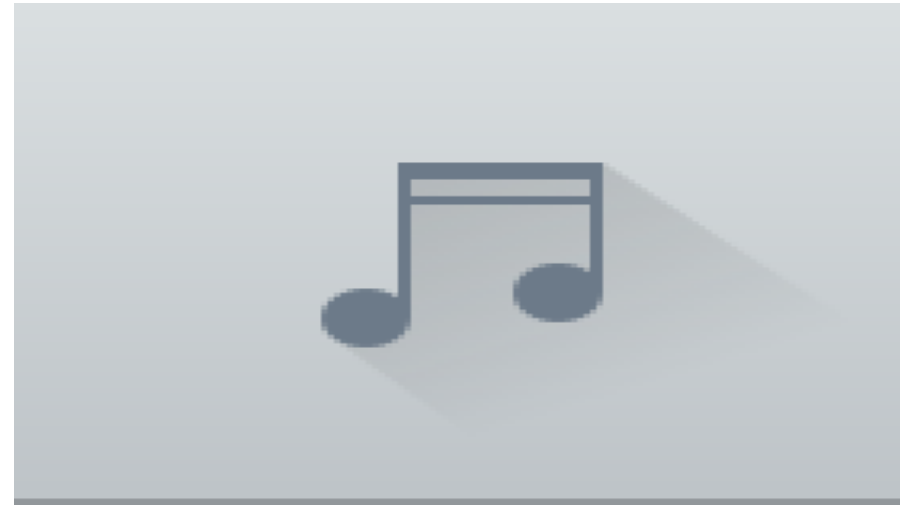
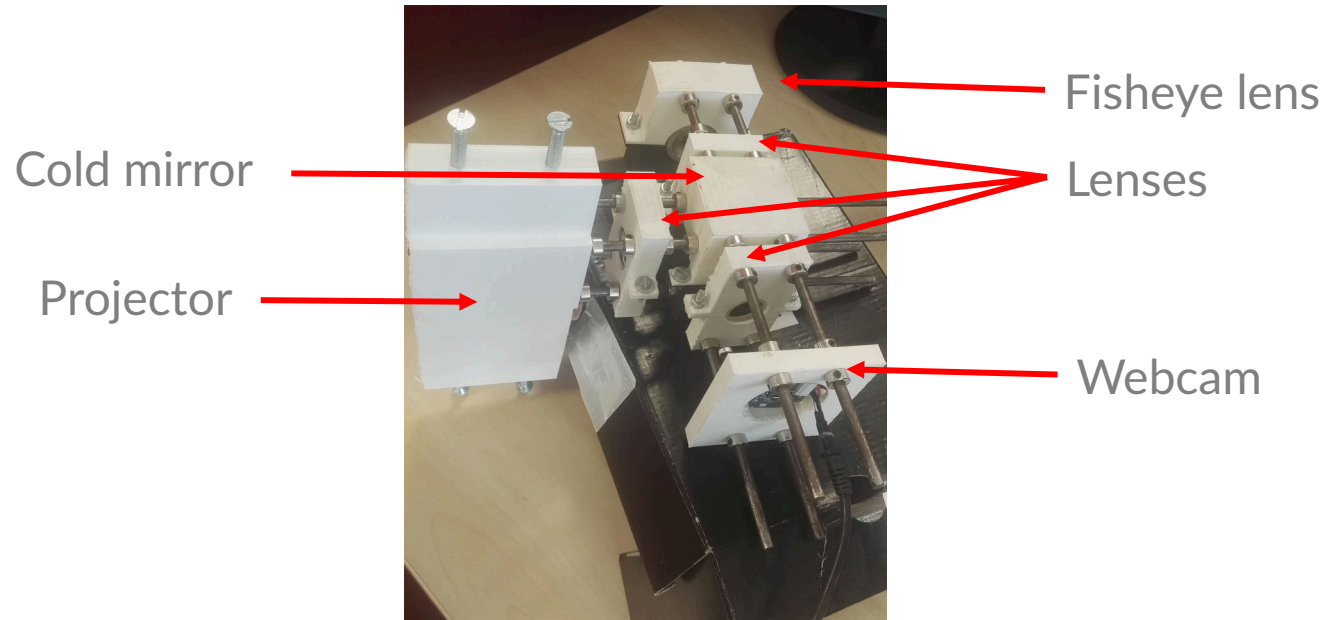
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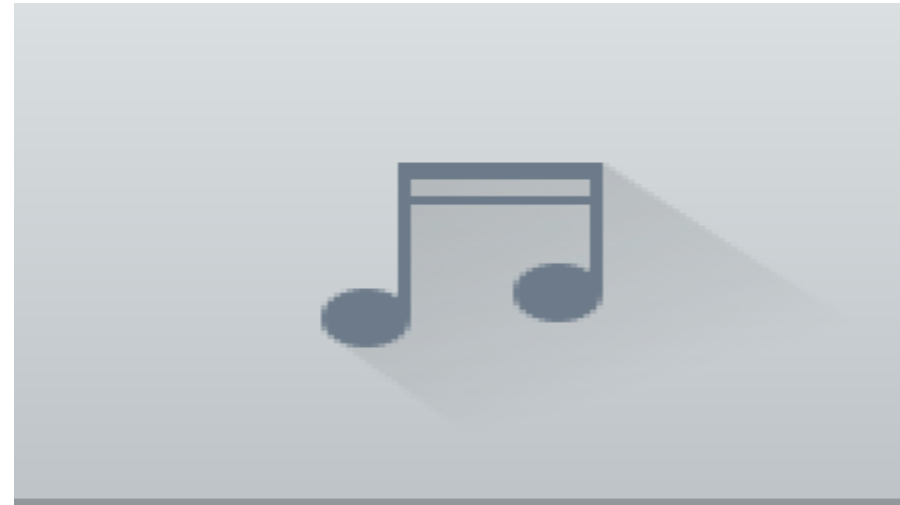
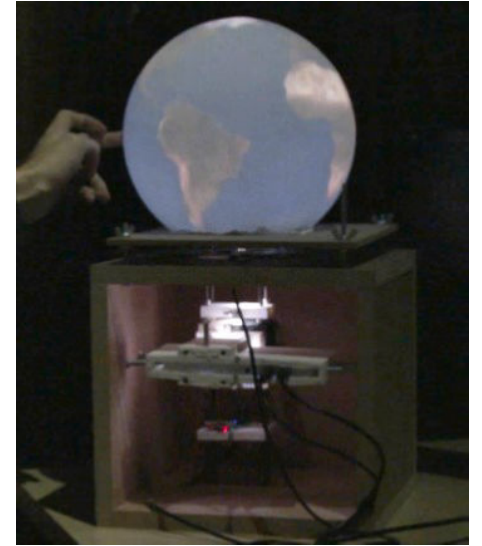
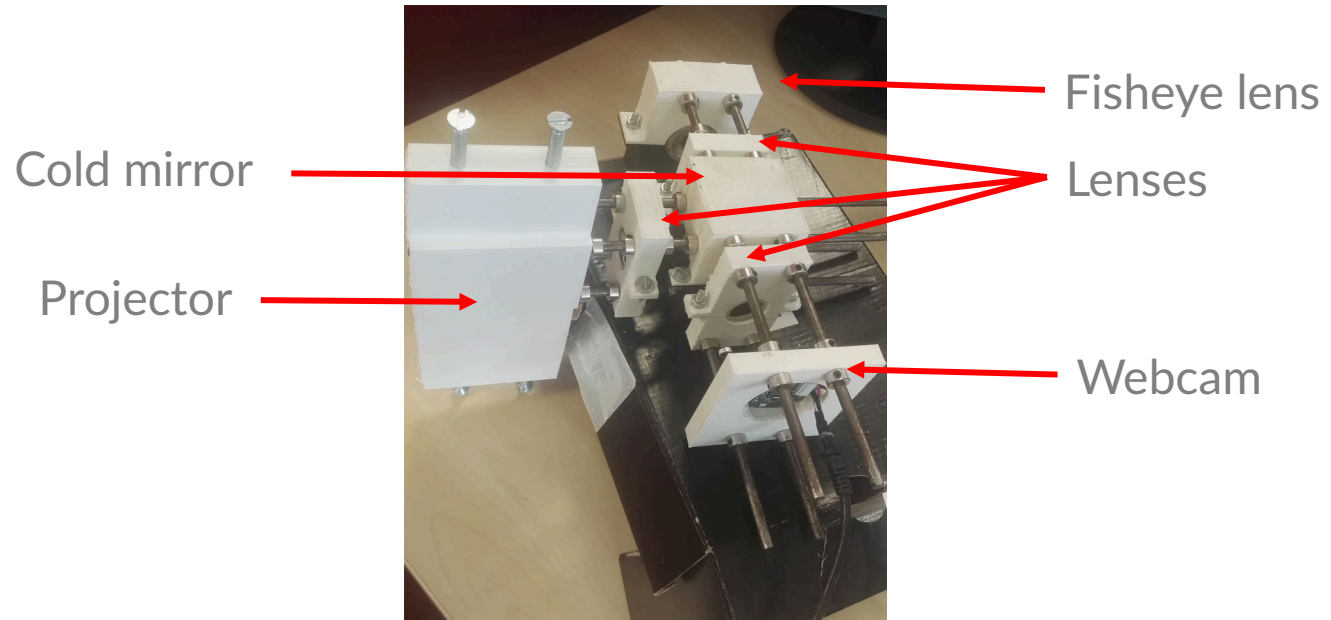


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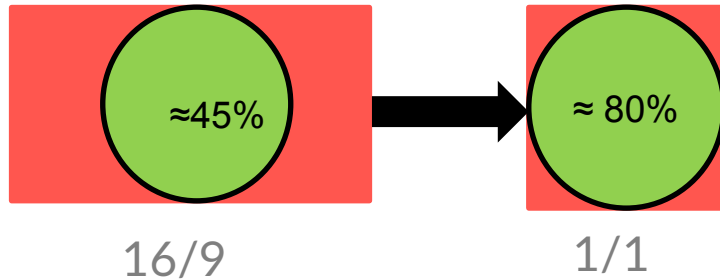


# Summary

- Multitouch spherical display without the need of custom shaped lenses
- LBS projector + Infrared finger tracking
- Optical system to cover the full sphere and maintain a sharp image
- Software corrections to compensate the cheap components
- Working prototype for less than \$600
- Approximative resolution : 620k pixels
- Low brightness

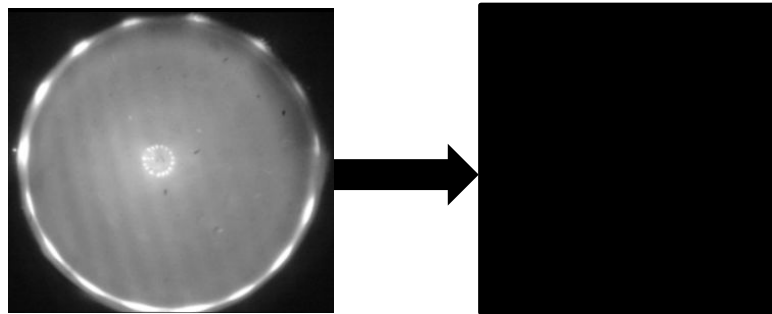
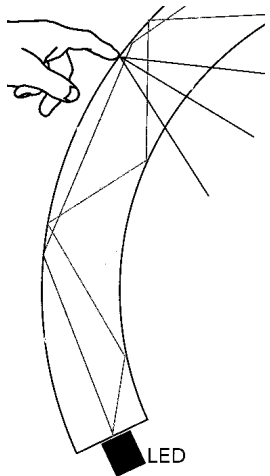
# Future work

## Anamorphic system



- Aspect ratio 1:1
- Increase brightness and resolution
- Examples : prism pair, cylindrical lenses...

## Frustrated total internal reflection



- Common for planar surfaces
- Compatible for spherical surfaces
- Darker background image

But :

- Transmissive surface vs. diffuse surface

Thanks!  
Questions?

Thomas Crespel  
thomas.crespel@inria.fr

