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Calibration of Multiple Cameras and Projectors

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Acknowledgment

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- Webpage: https://www.fer.unizg.hr/3dcoding/en

Problem Statement

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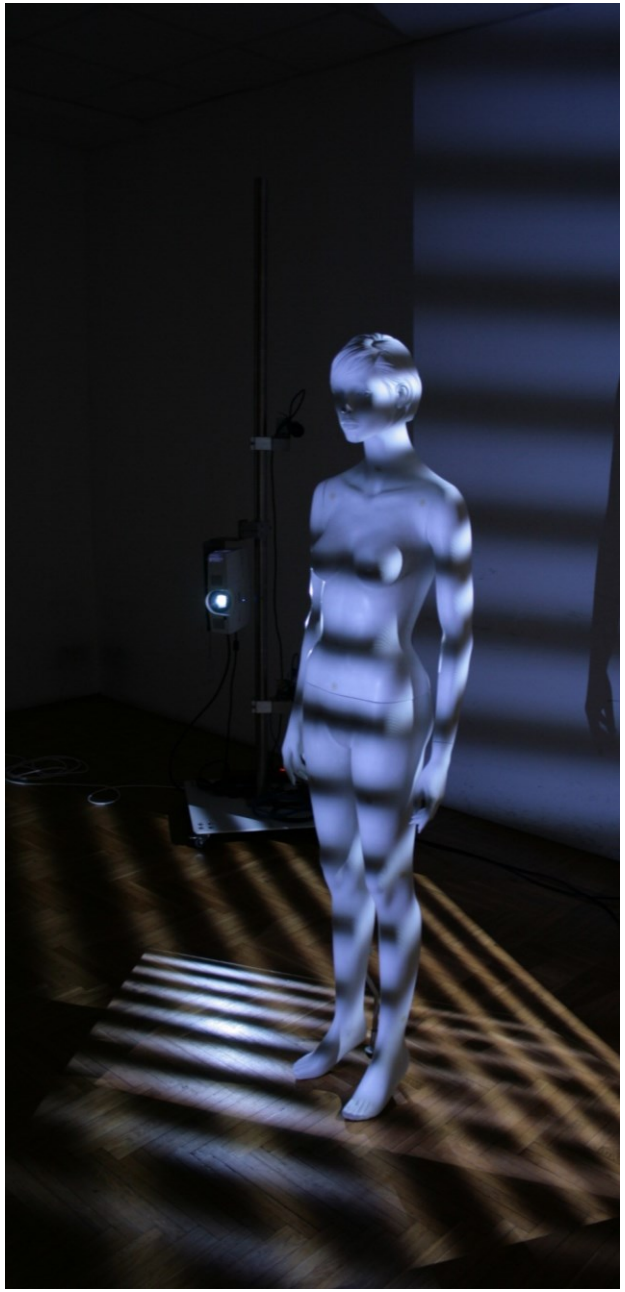
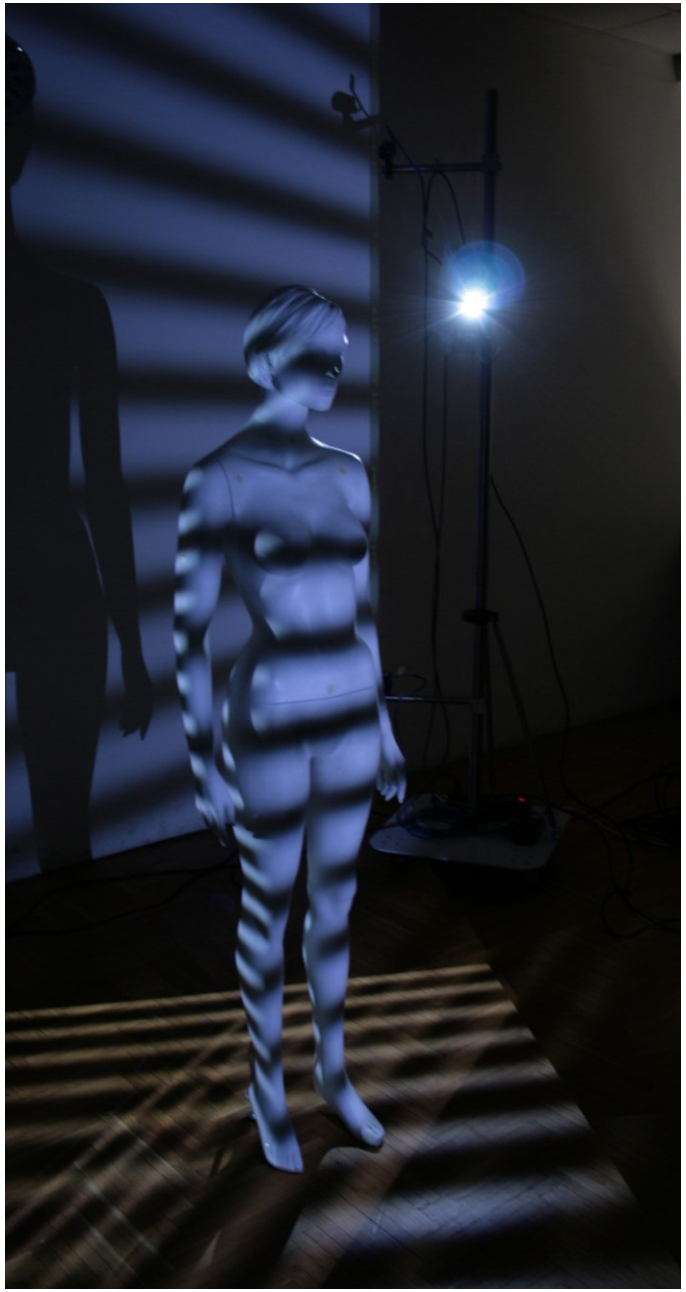
- **Geometric** calibration must be performed before an imaging system can be used
  - camera calibration is well understood
  - projector calibration is more difficult, especially when more projectors are used
- A simple and robust calibration procedure for simultaneous calibration of multiple cameras and projectors is required
- **Photometric** and/or **colorimetric** calibration may also be performed
  - Geometric and photometric/colorimetric calibrations are independent and are usually performed separately





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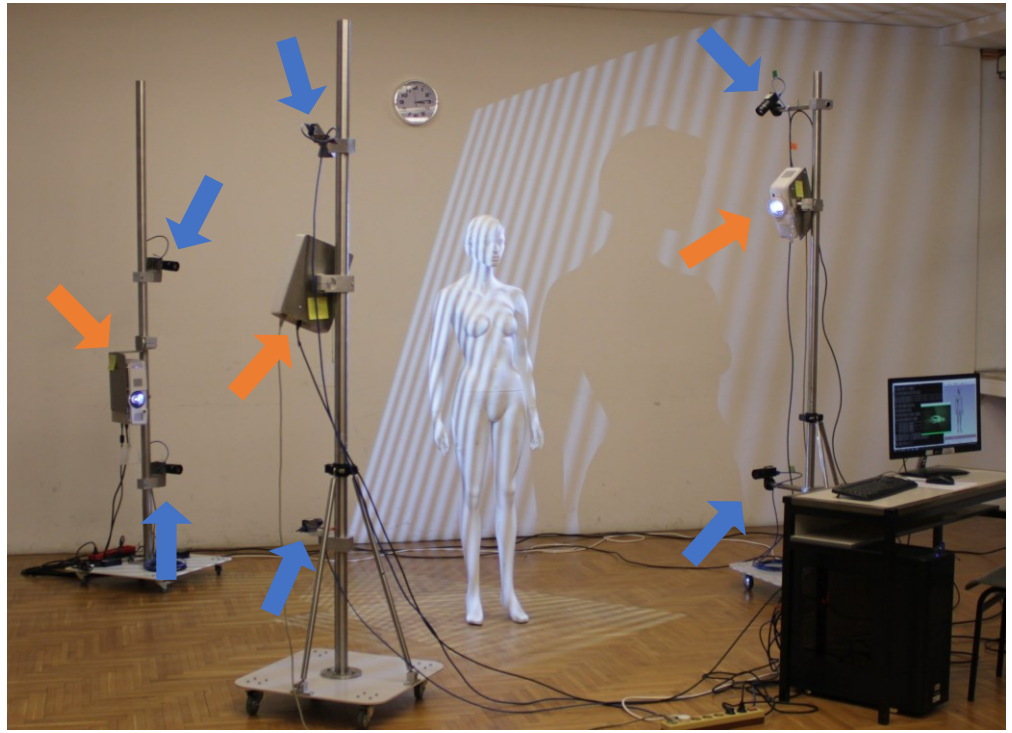

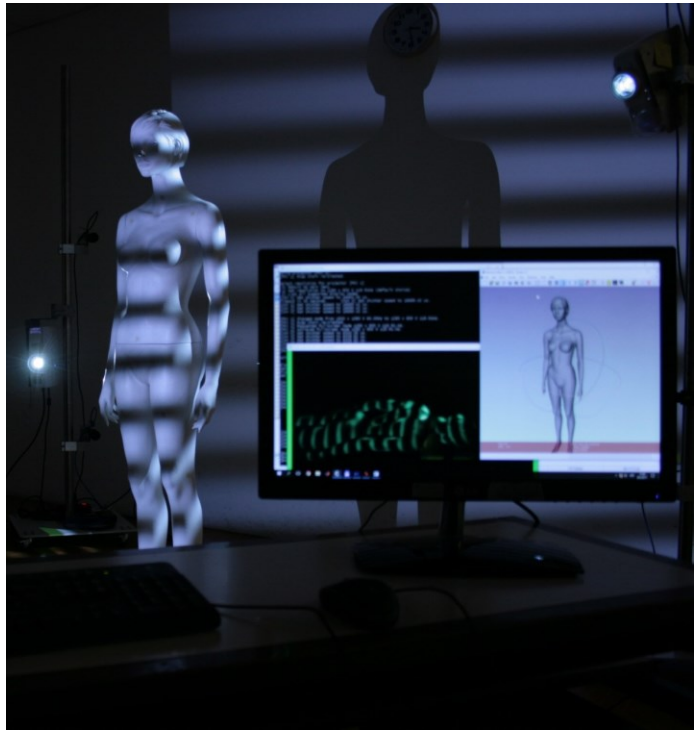

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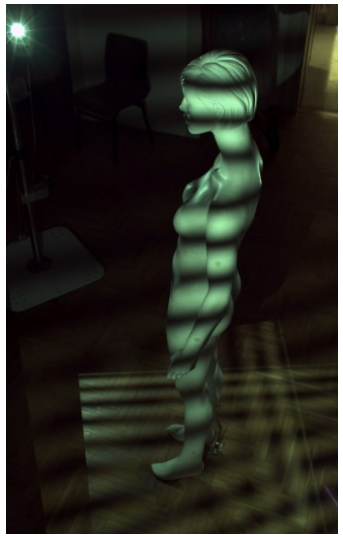

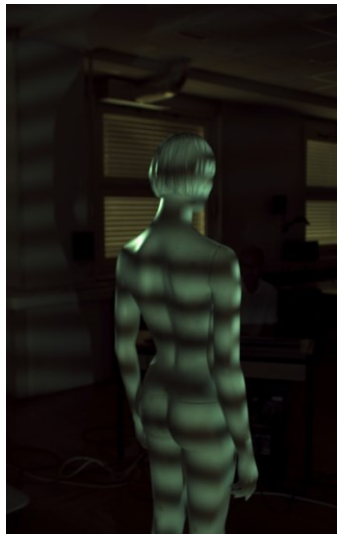

Calibration Objects

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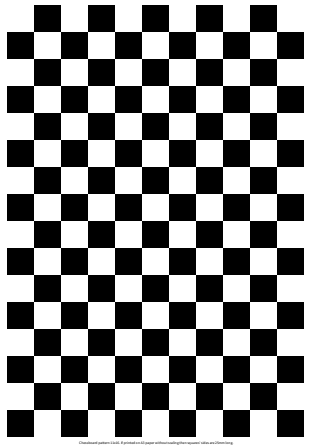
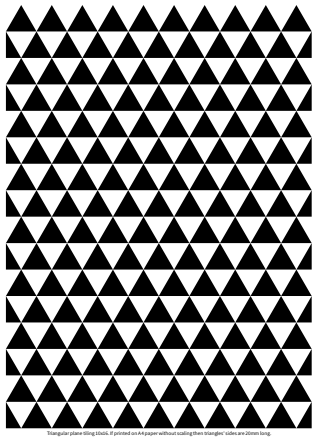
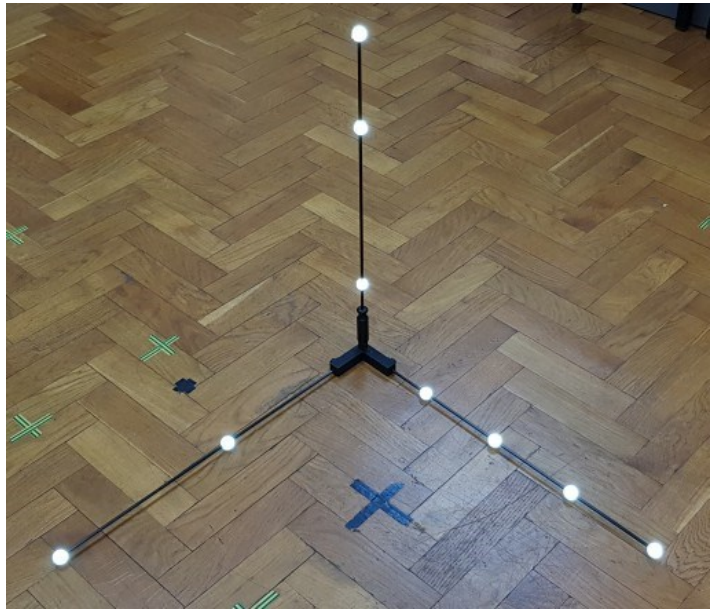
1D: calibration wands

2D: calibration boards





3D: calibration cages



Projector Calibration

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- Projector cannot acquire images
  - must use camera(s) to acquire the data required for calibration
- Modern approaches employ ideas from structured light scanning
  - a planar calibration board is used; most often bright circles on dark background
  - projector projects a code which directly embeds projector's row and column coordinates
  - decoding the projected code provides a direct mapping (a planar homography) between camera's and projector's image coordinate systems
- Projector is modelled as an inverse camera
  - a pinhole camera model with distortions

Calibration Pattern

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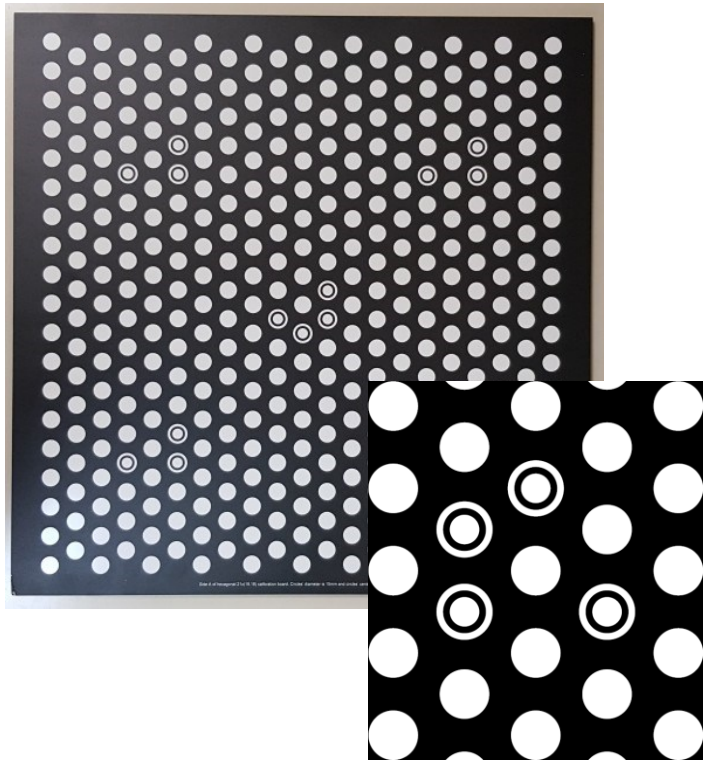

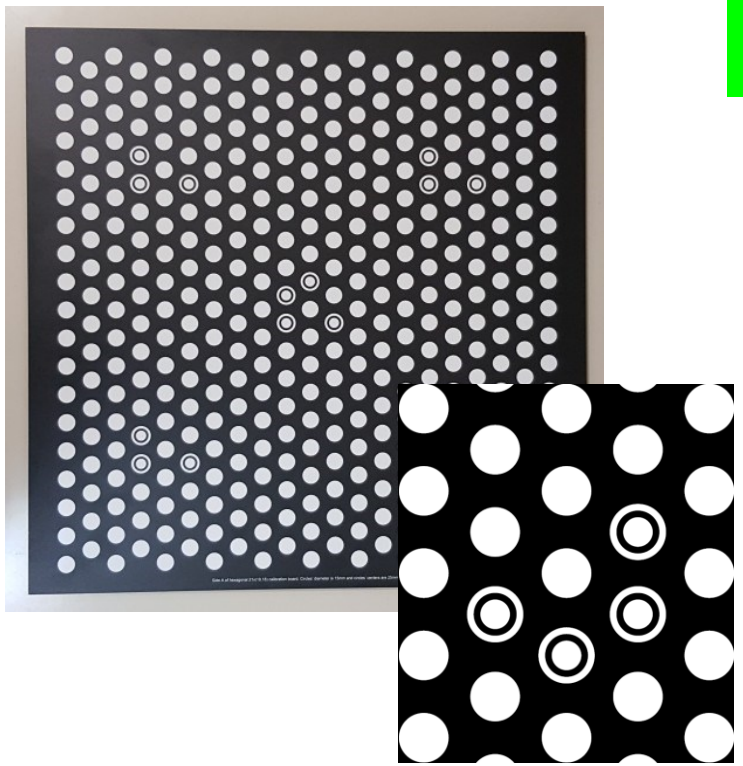

- We propose to use a double-sided calibration board containing bright circles placed in a hexagonal lattice and side identifications markings

Pattern Processing

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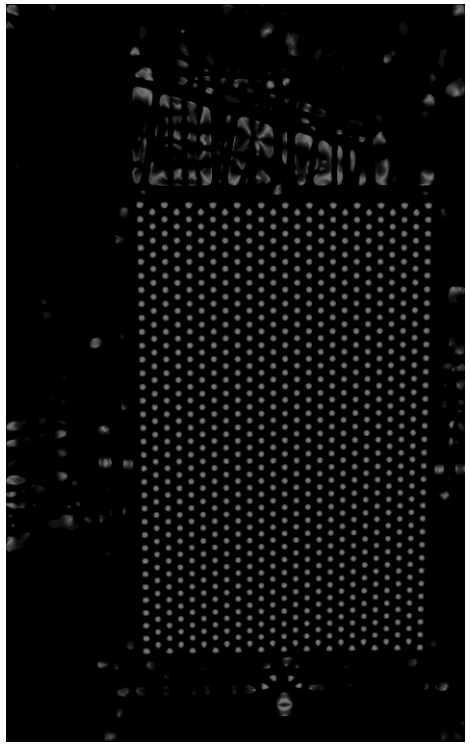
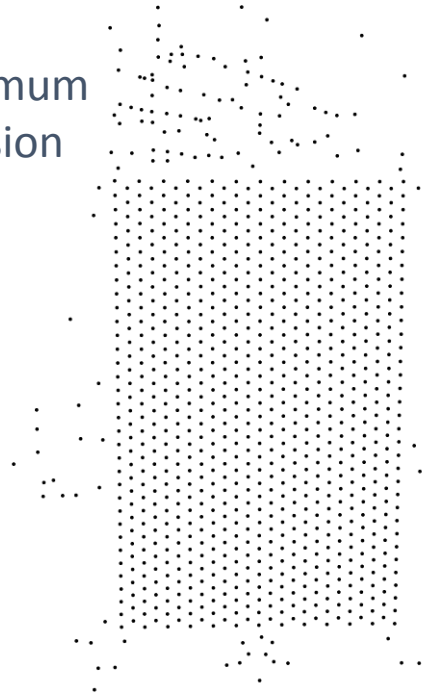
scale-space
detection
of
circles



circle
center
detection
with
non-maximum
suppression



Extracted Grids

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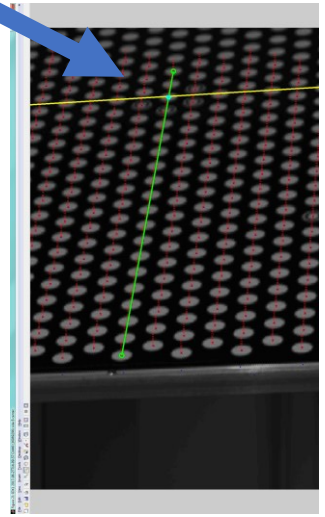

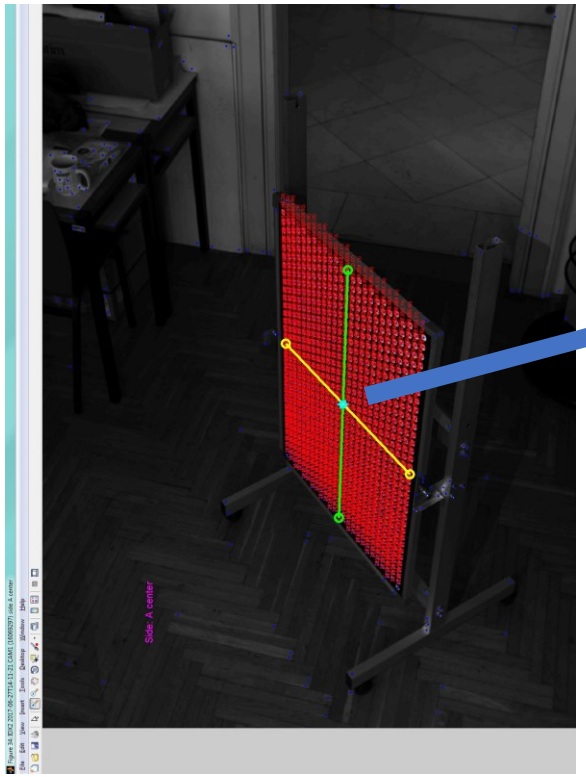

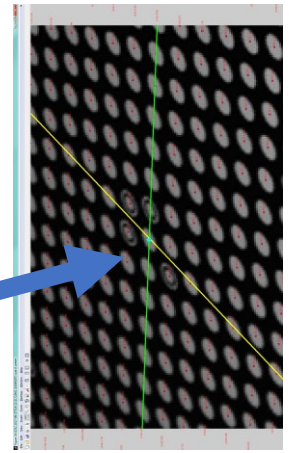

Bundle Adjustment

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- Scale-space approach to circle detection eliminates almost all user selectable parameters
- A bottom-up approach to hexagonal grid construction is robust and automatically handles oblique board positions and partial pattern visibility
- Extracted image point coordinates are input to the standard bundle adjustment procedure
  - re-projection error is simultaneously minimized for all cameras and for all projectors in the system

Colorimetric Calibration

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- We are usually interested in colorimetric calibration so we can reproduce colors faithfully
  - Photometric calibration is only required if we want to measure intensities in physical units
- Projector and camera cannot be decoupled
  - Projector can be geometrically calibrated using an uncalibrated camera, but cannot be photometrically calibrated
  - Camera and projector are usually simultaneously calibrated using self-calibration, i.e. calibration object is not required

Colorimetric Calibration

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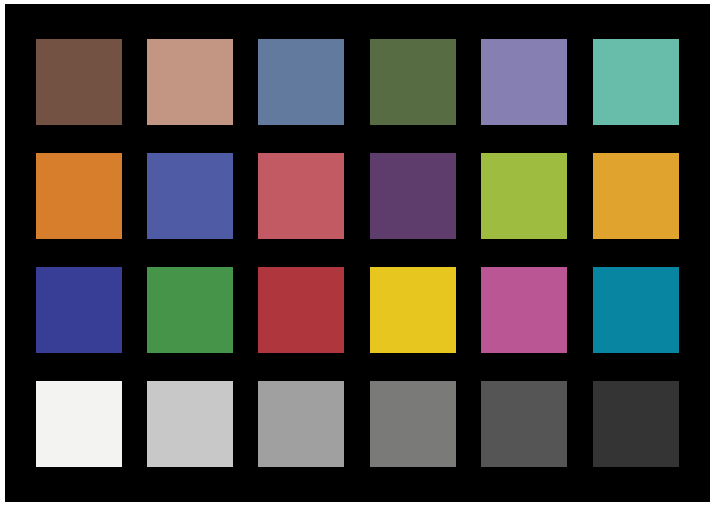
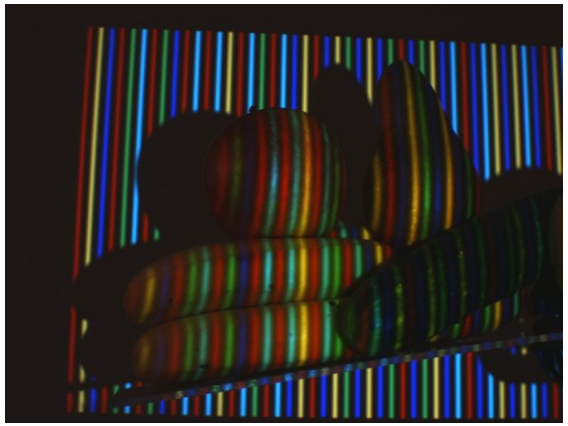
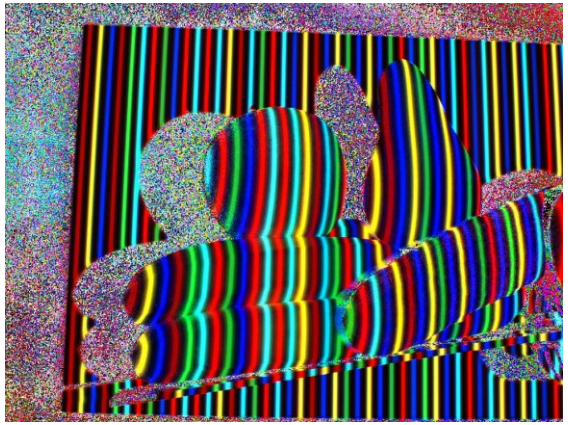
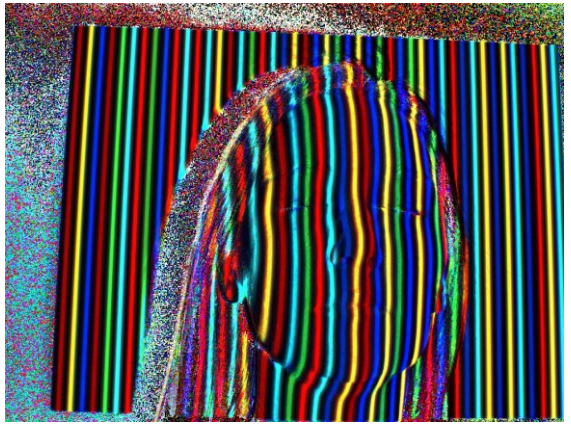
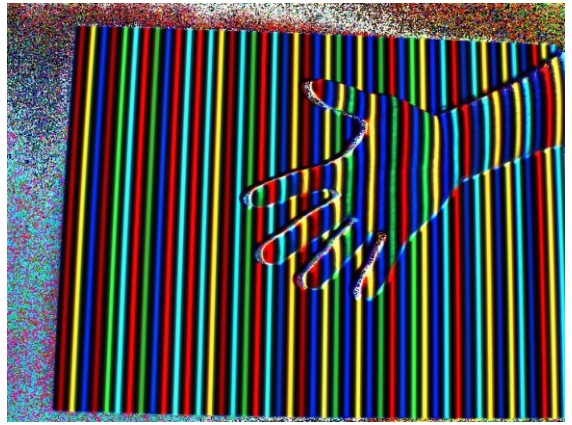


standard colorimetric
calibration board



Future Work

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- Geometric and photometric calibration for refractive geometries and underwater imaging
  - both camera and projector are looking at objects immersed in water

tank will be filled with water

glass between water and air forms a refractive boundary

cameras and projector will look through the glass

Conclusion

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- A practical geometric calibration method to calibrate a system comprised of multiple cameras and projectors
- Easy to use in practice and allows us to calibrate a complex imaging systems quickly and efficiently
- Please send any questions (and research and collaboration ideas) to tomislav.petkovic.jr@fer.hr
- Thank you for your attention