Towards Efficient 3D Calibration for Different Types of Multi-view Autostereoscopic 3D Displays

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Background and Introduction (3D display)

- Stereoscopic display
  - Binocular parallax
  - Wearing glasses (uncomfortable)
- Glasses-free 3D display
  - Holographic display (phase)
  - Volumetric display (voxel)
  - Multi-view display (rays’ direction)
  - Light field display (rays’ direction)
  - Integral imaging display (rays’ 2D direction both in horizontal and vertical, e.g. similar with random hole display)
Background and Introduction (Calibration)

- Calibration for 3D display
  - Calibration of projection-based light field display
    - 2D calibration of the projecting image on the screen for each projector in sequence
    - Utilization of the rotating CCD camera
  - Calibration of lenticular multi-view display
    - Solve the angular misalignment of the lenticular sheet in front of the LCD
    - Analyze the misalignment based on the geometry

Motivation of the research

• Main drawback of current autostereoscopic displays
  – Crosstalk of different views at different viewing distances
  – Misalignment of the optical and mechanical devices
  – Manufacture and installation error (mechanics and optics)

How to solve get better display for all the viewers?
Motivation of the research

• The motivation of our work
  – From the user end (viewer’s eyes) to get better 3D images
  – To get the correct relationship between the display and the viewing positions
  – Eliminating or reducing the crosstalk or ghosting image for the limited users
Universal 3D calibration for multi-view 3D display (Overview)

- Simplify 3D display to a 2D panel \((M \times N)\)
- Each unit emits rays with \(U \times V\) directions
- Camera locates at the viewpoint

**Calibration target:**
To get the ray \(L\) from unit \(Q(x, y)\) with the \((u, v)\) direction to hit the camera

- Gray code pattern is to reduce the number of capturing images for this viewpoint from \(M \times N \times U \times V\) to \(\log_2(M \times U) + \log_2(N \times V)\)
Universal 3D calibration for multi-view 3D display

- **Initialization of the camera**
  - Get the camera’s intrinsic parameters

- **Capture at each random sampled position with gray code patterns**
  - Transform the camera location to the display reference (world coordinate) \( X_C \)
  - Get the dataset of the corresponding rays \( L_C(x, y, u, v) \) for this camera position \( X_C \)
    \[
    \{(X_{Ck}, L_{Ck}) | k = 1: K\}
    \]

- **Interpolation for a arbitrary viewpoint** \( X \)
  - Interpolate the corresponding rays \( L(x, y, u, v) \)
  - the camera arbitrary viewpoint \( X \)
Testing of the Calibration Method

- Implementation of the calibration on the commercial 3D display (Alioscopy)

- Implementation of the calibration on the developed 3D display based on directional backlight
Implementation of the calibration method on Alioscopy 3D display

- Alioscopy 3D TV (47”)
  - LCD + lenticular sheet
  - Native resolution: 1080p
  - 8 views
  - Optimized viewing distance: 4.4m
  - Sweet spot width: 52cm (~8 * IPD)

- Sub-pixel arrangement
  - Slanted lenticular lens
  - One lens covers 8 sub-pixels in horizontal direction
Implementation of the calibration method on Alioscopy 3D display

• Experiments
  – Put camera in the optimized viewing distance
  – Use different letters for the 8-view input
  – Capture photos at 8 different views
    • Less crosstalk
Implementation of the calibration method on Alioscopy 3D display

- Experimental results
  - Viewer #1 & #2 (4 eyes) at different depths
  - Viewer #1 (“AB” & “CD”);
    Viewer #2 (“EF” & “GH”);
  - Comparison

- Without calibration, more ghosting
- With calibration, nearly clear image
Implementation of the calibration method on multi-view 3D display based on directional backlight

- **Configuration**
  - Projector
  - LCD
    - Without backlight
  - Optical module
    - Field lens
    - Two vertical diffuser
    - Slanted cylindrical lens array
  - PC
  - Eye-tracking module
    - Kinect v1 or Kinect v2
Principle of the developed multi-view 3D display based on directional backlight

- **Mapping relationship in the design**
  - Ray’s direction is dependent on the projecting pixels from the projector
Implementation of the calibration method on multi-view 3D display based on directional backlight

- Experiment & Result
  - Support two viewers at different distances
  - Put camera at multiple random positions to sample corresponding backlight
  - Interpolate the backlight for two viewers (4 eyes)
    - Arbitrary position in the viewing volume
    - Clear image without ghosting
Conclusions & Future work

• A novel and efficient 3D calibration method for different types of multi-view autostereoscopic 3D displays
  - Consider from the user-end to reconstruct the relationship between the user and display
  - Utilizing the gray-code patterns to accelerate the capturing process
  - Tested the universal method in two different types of 3D displays and verified this efficient calibration method

• Future work
  - Add a user-tracking module to enable the display render in real-time
  - Reduce the number of captured images with some deep-learning methods to improve the capturing process
Thanks for your kind attention!