Animated Stickies:

Fast Video Projection Mapping onto a Markerless Plane through a Direct Closed-Loop Alignment

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Project Page: http://www.ic.is.tohoku.ac.jp/en/rtsense/animated_stickies/

18th IEEE International Symposium on Mixed and Augmented Reality
October 16, 2019

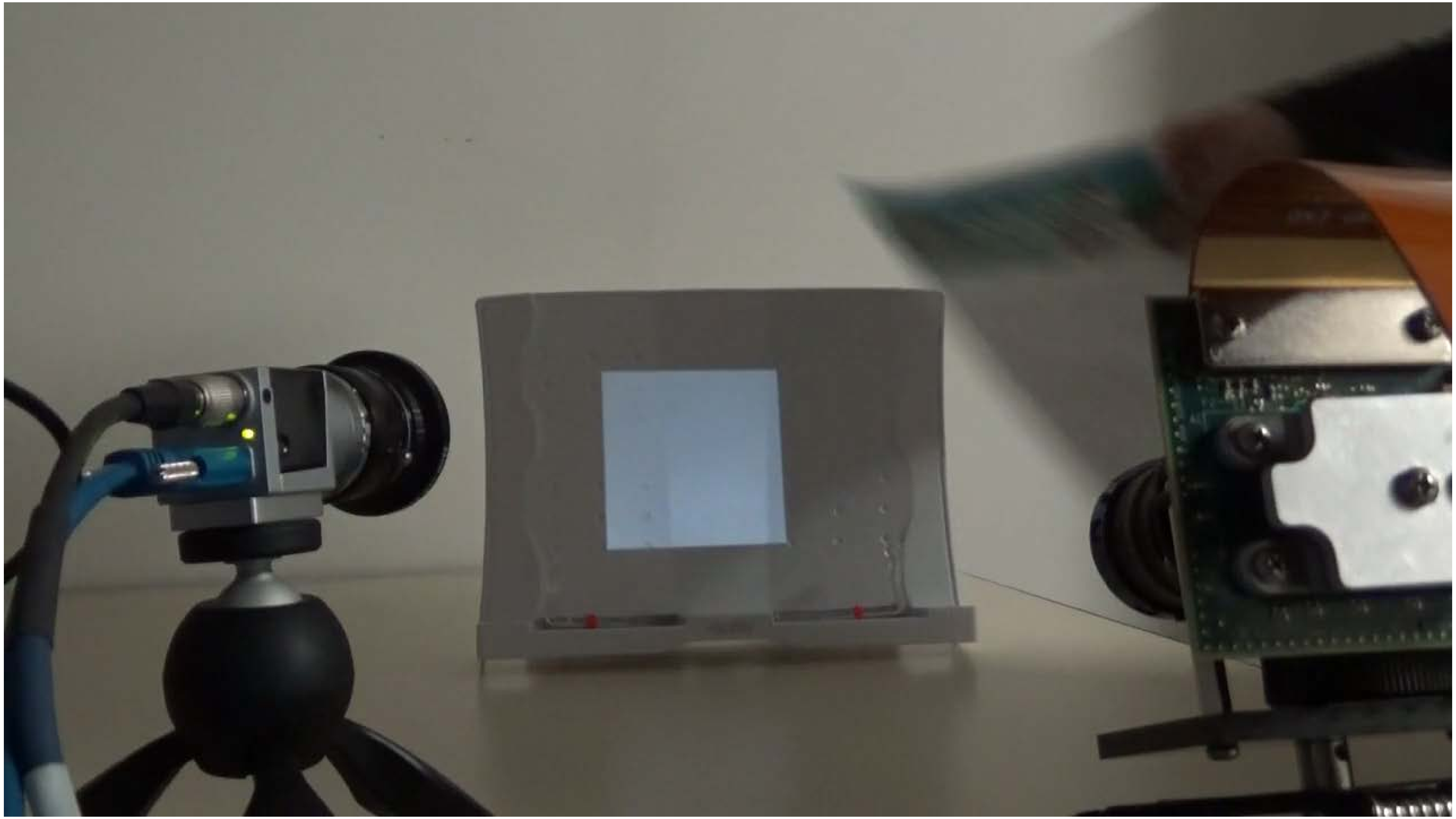
Overview

Two Aspects of Contribution:

- Low-Latency Spatial AR/MR
  - Hardware aspect
- Calibration-less and Marker-less Spatial AR/MR
  - Algorithm aspect

- Algorithm Pipeline
- Results
- Limitations
- Conclusions

Contribution 1: Low-Latency Spatial AR/MR



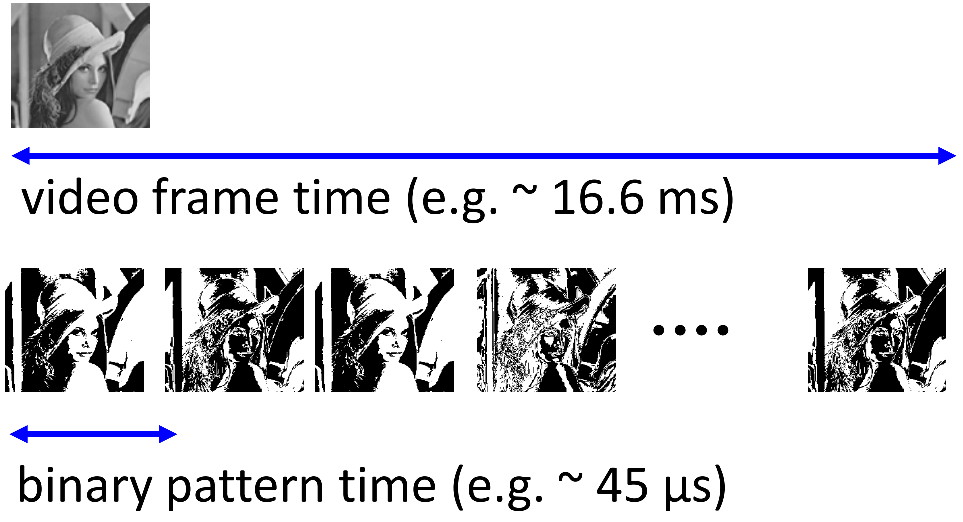
DLP-based High-Speed Projection

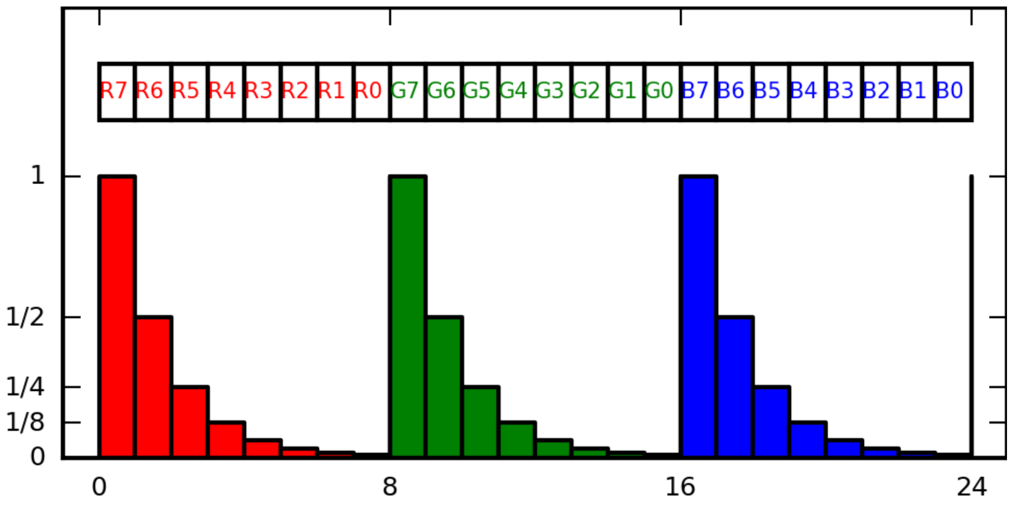
In recent years, several institutes and companies achieved such fast projection mapping apps using Digital Micromirror Device (DMD)

- Kagami+, SIGGRAPH Asia 2015 E-tech
- Watanabe+, IDW 2015
- Panasonic, CES 2016, InfoComm 2017
- Narita+, TVCG 2017
- Bermano+, CGF 2017
- Kagami+, SIGGARPH 2018 E-tech

Two approaches:

- Increase the frame rate by reducing the number of binary patterns (with help of light source brightness modulation)
- Lower the latency without increasing the frame rate

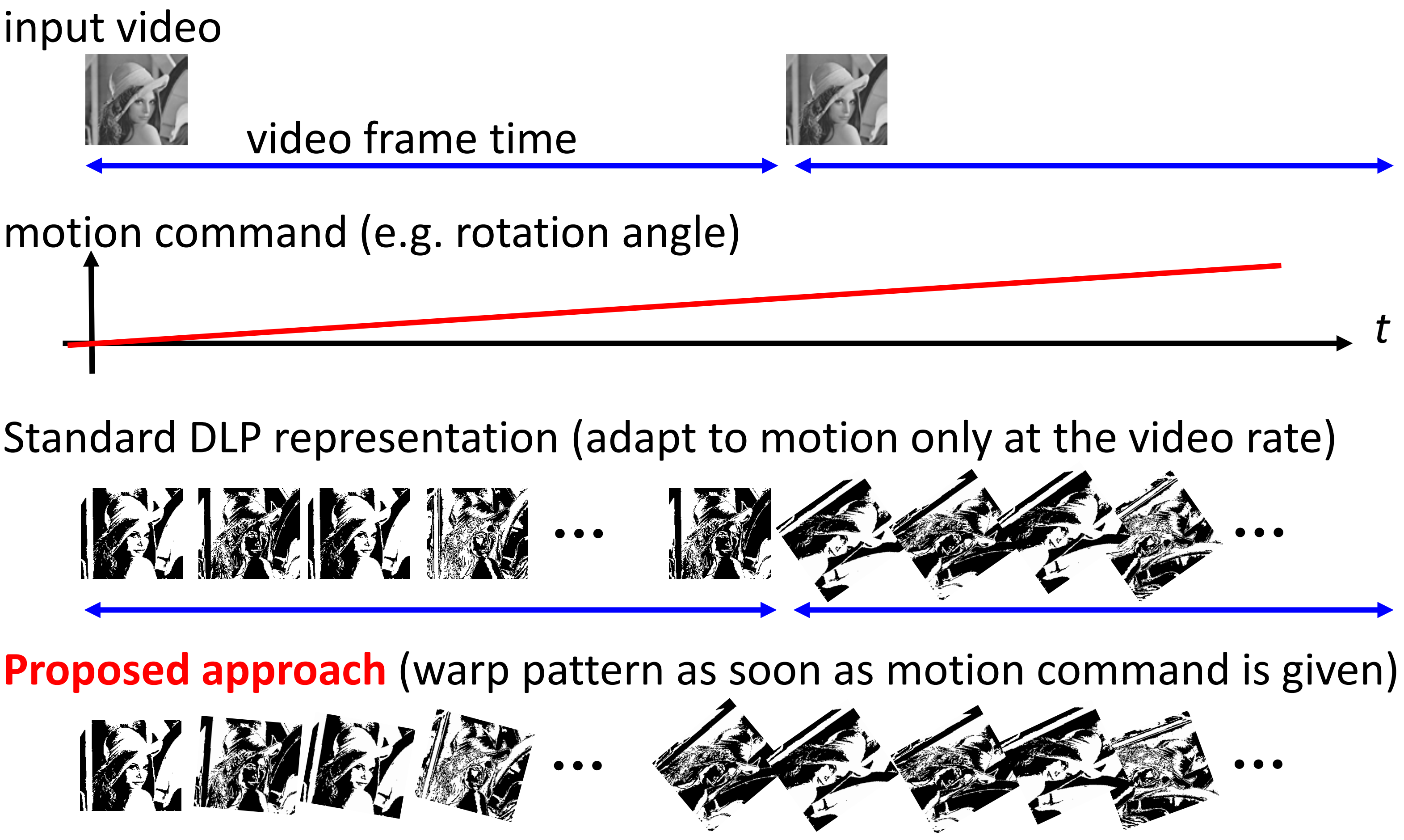




A light source sequence to display 24-bpp images in 24 binary patterns

Our Approach [Kagami+ SIGGRAPH Asia 2015 E-tech]

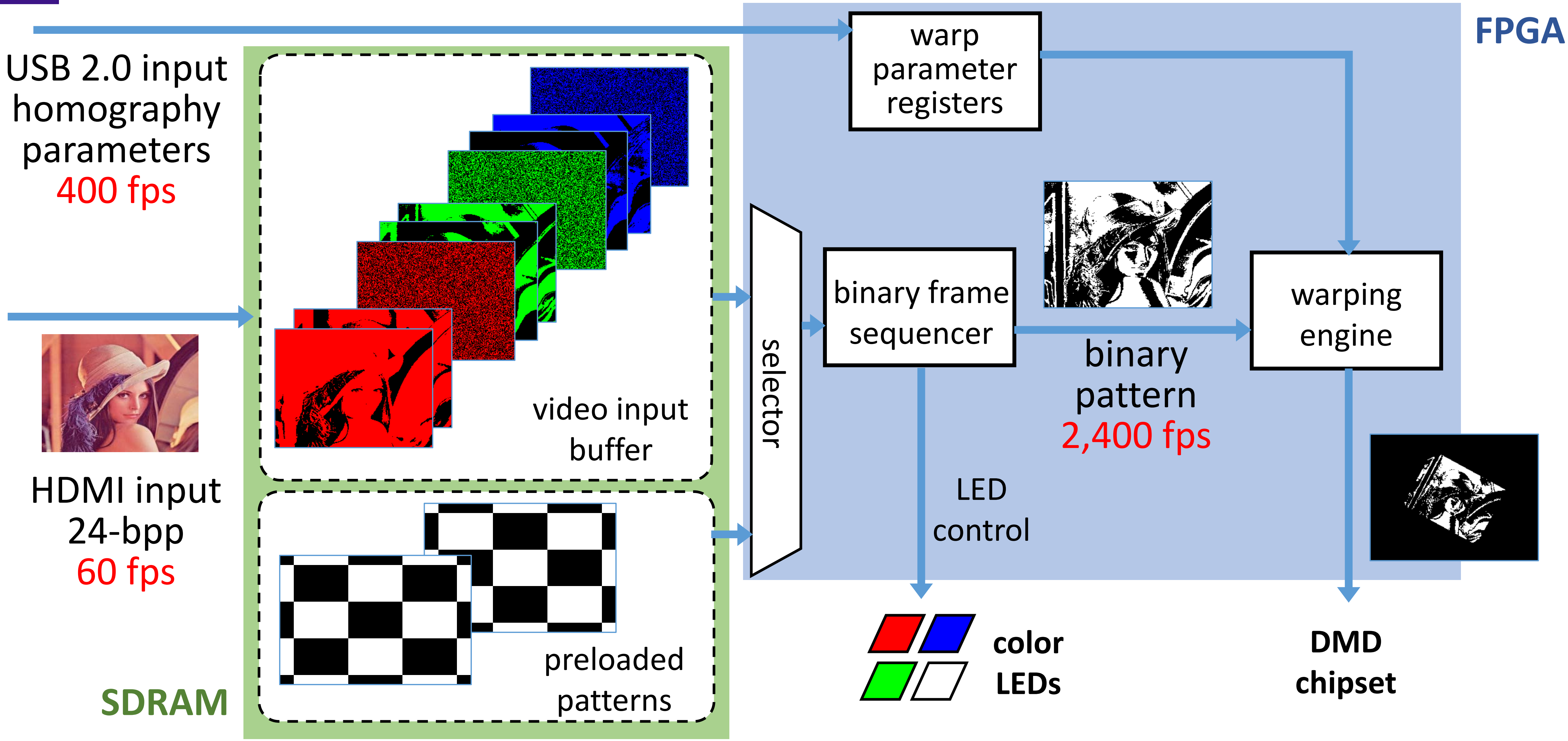
Warp each pattern, instead of a set of patterns composing a video frame



Kagami+ SIGGRAPH 2018 E-tech

Similar in spirit to those for low-latency HMDs (Zheng+ ISMAR 2014, Lincoln+ TVCG 2016)

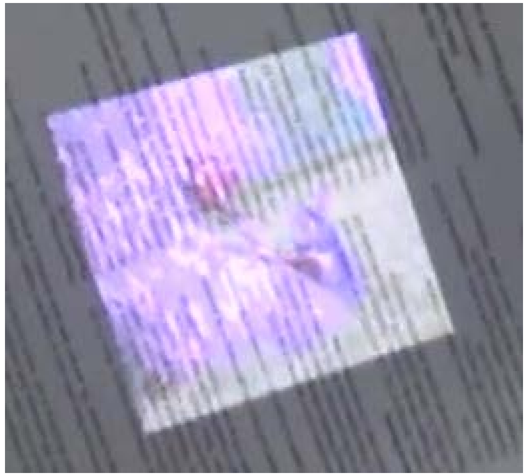
Our Hardware Pipeline



Contribution 2: Calibration-free and Marker-free Mapping

Closed-loop Registration in AR/MR

Track not only the surface but also the projected content



Challenges:

- interference between projected light and surface texture
- dealing with movie content

Incorporating the interference into the optimization process is possible, but computationally intensive

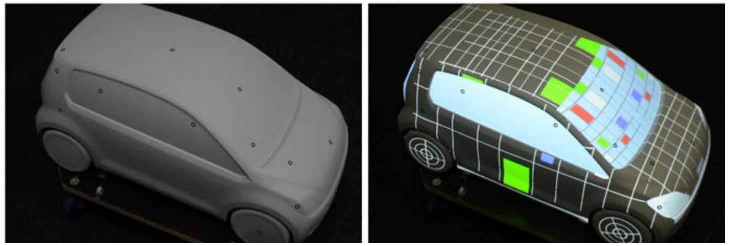
- Audet+ CVPR 2010, Virtual Reality 2013
- Nakamura+ ICPR 2012
- Zheng+ IEEEVR 2013

Often worked around by assuming a known-shape solid-color surface

known 3D shape

Johnson+ ProCams2007

known 3D shape



Resch+ TVCG 2016

known 2D projective shape

Kagami+ SA2015, S2018

Closed-loop Registration in AR/MR

Challenges:

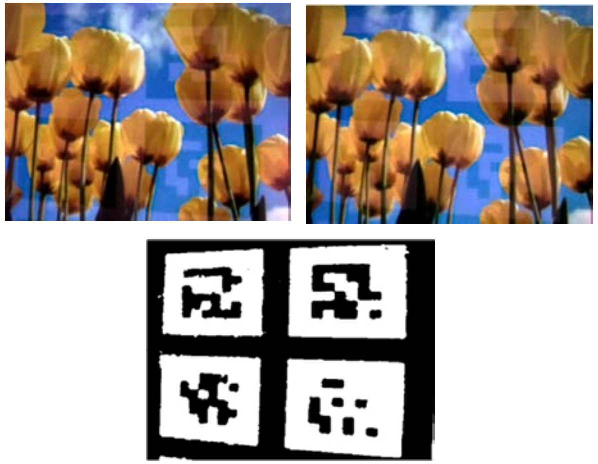
- interference between projected light and surface texture
- dealing with movie content (how to track?)

"Embedded code" approach is

- effective in solving this issue
- suitable for fast flapping DMD

- Raskar+ 1998
- Cotting+ 2004
- McDowall+ 2004
- Grundhöfer+ 2007
- Hiraki+ 2016
- Yamamoto+ 2017
- Kusanagi+ 2017

Raskar+ SIGGRAPH 1998



Grundhöfer+ ISMAR 2007

Again, we have to face the interference problem when surface texture exists

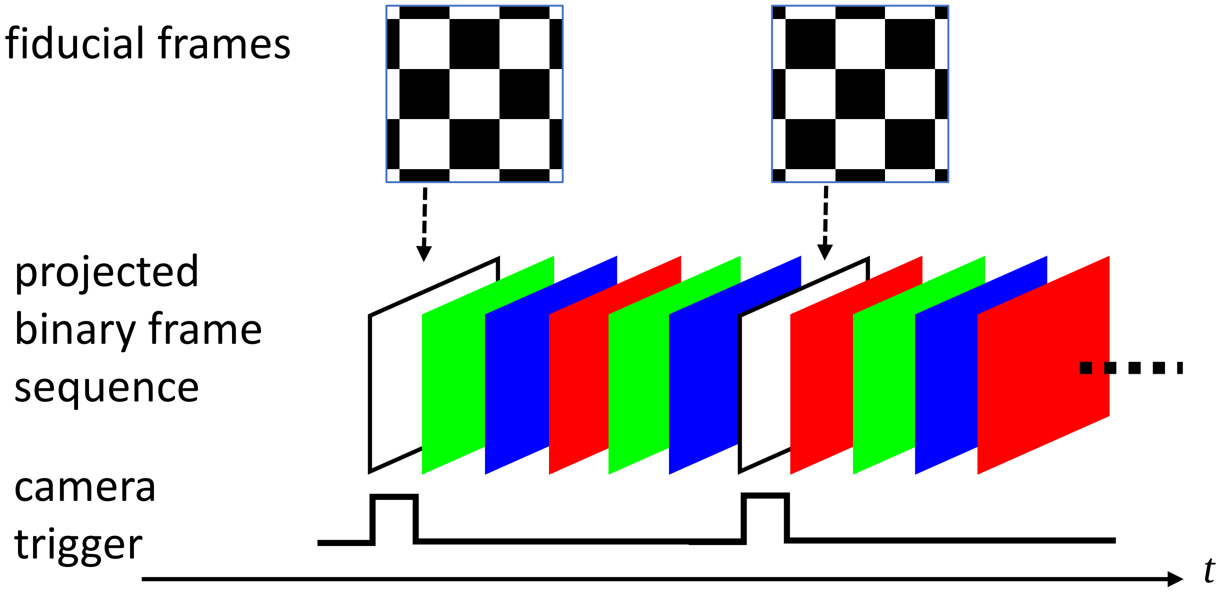
Multiple frames modulated by projected codes are often used:

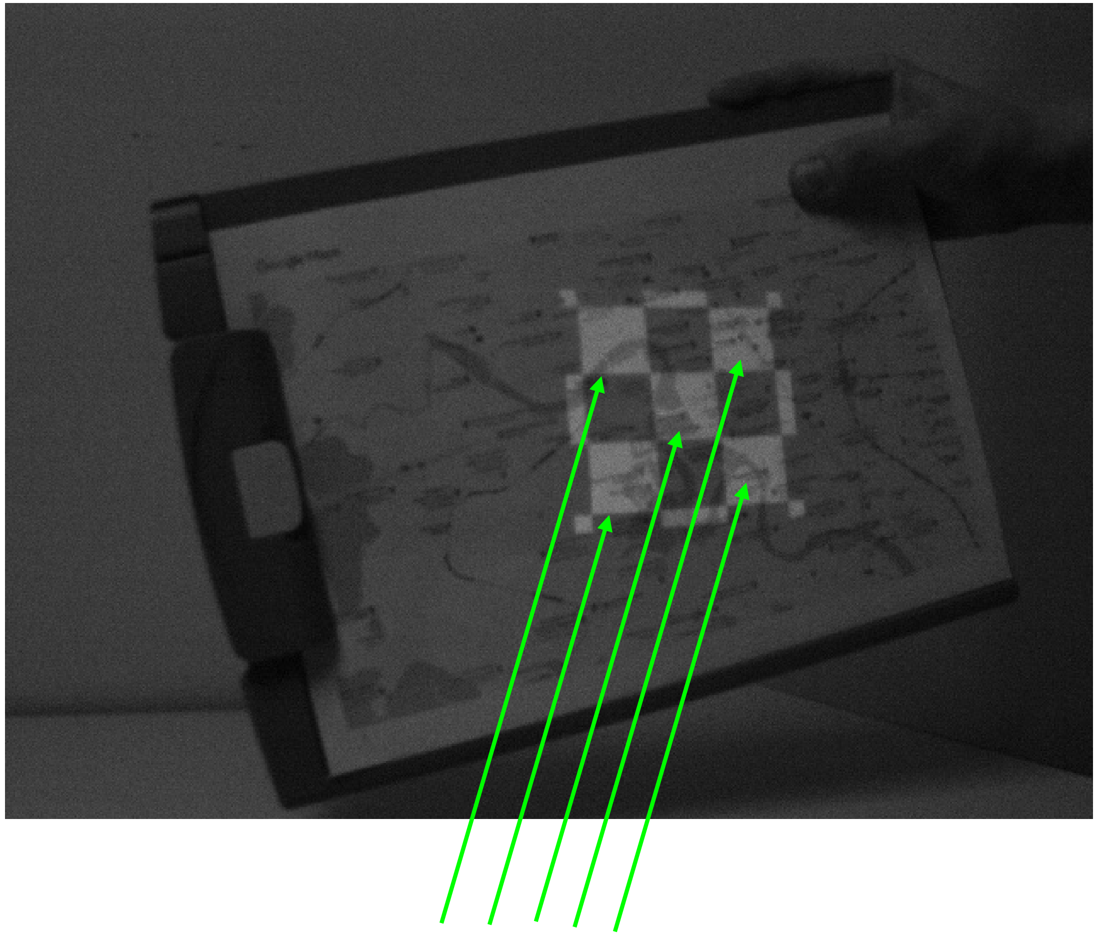
e.g. averaged to obtain surface texture

e.g. frame-differenced to obtain codes

Our Approach

Use a single frame to track surface and embedded code separately

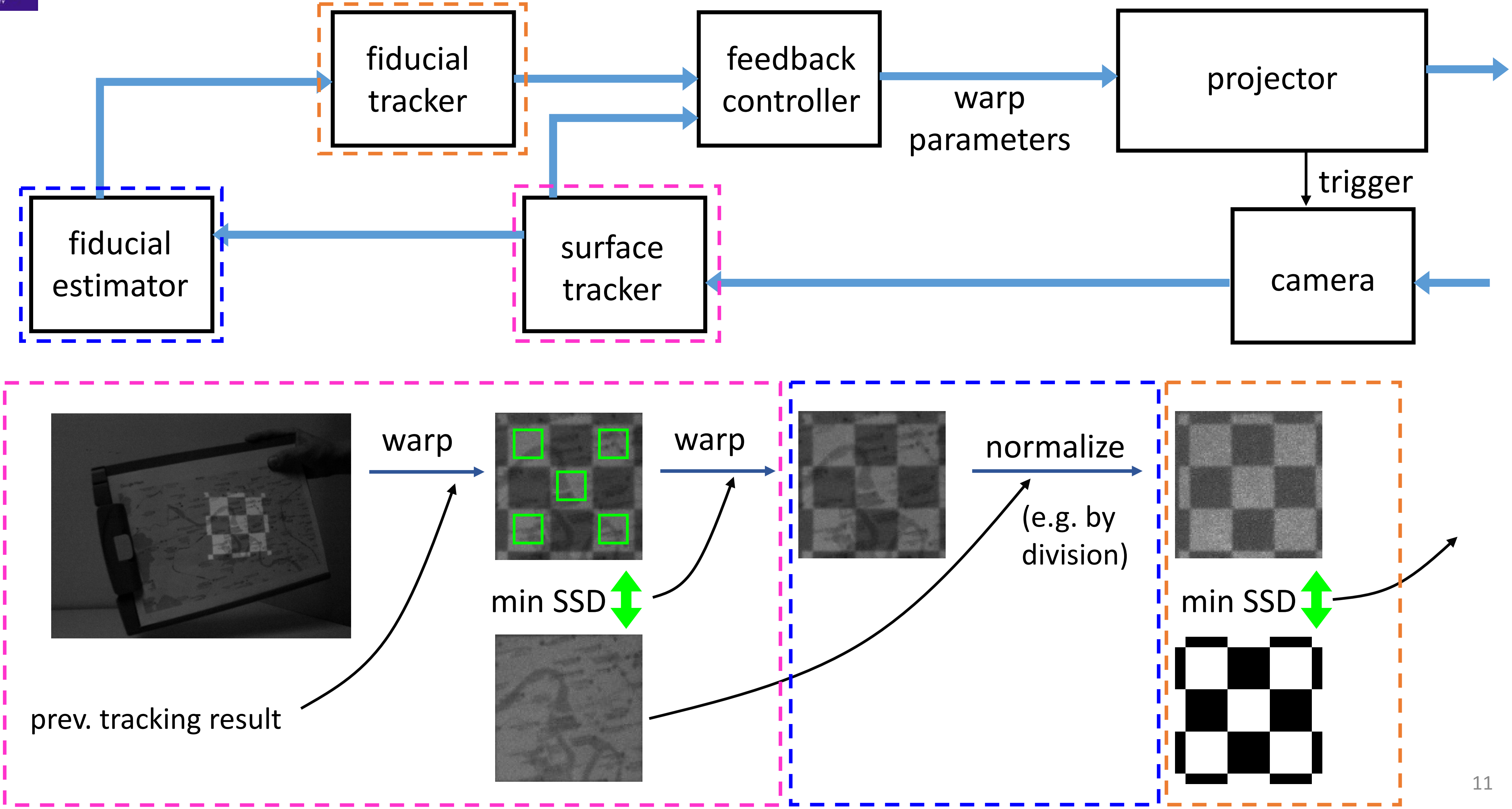




Key Observations:

- Surface tracking is possible if the fiducial pattern includes solid-color connected components with moderate sizes
- Once surface tracking is done, extracting a binary fiducial pattern is relatively easy

Proposed Algorithm Pipeline



Implementation Details and Timing Results

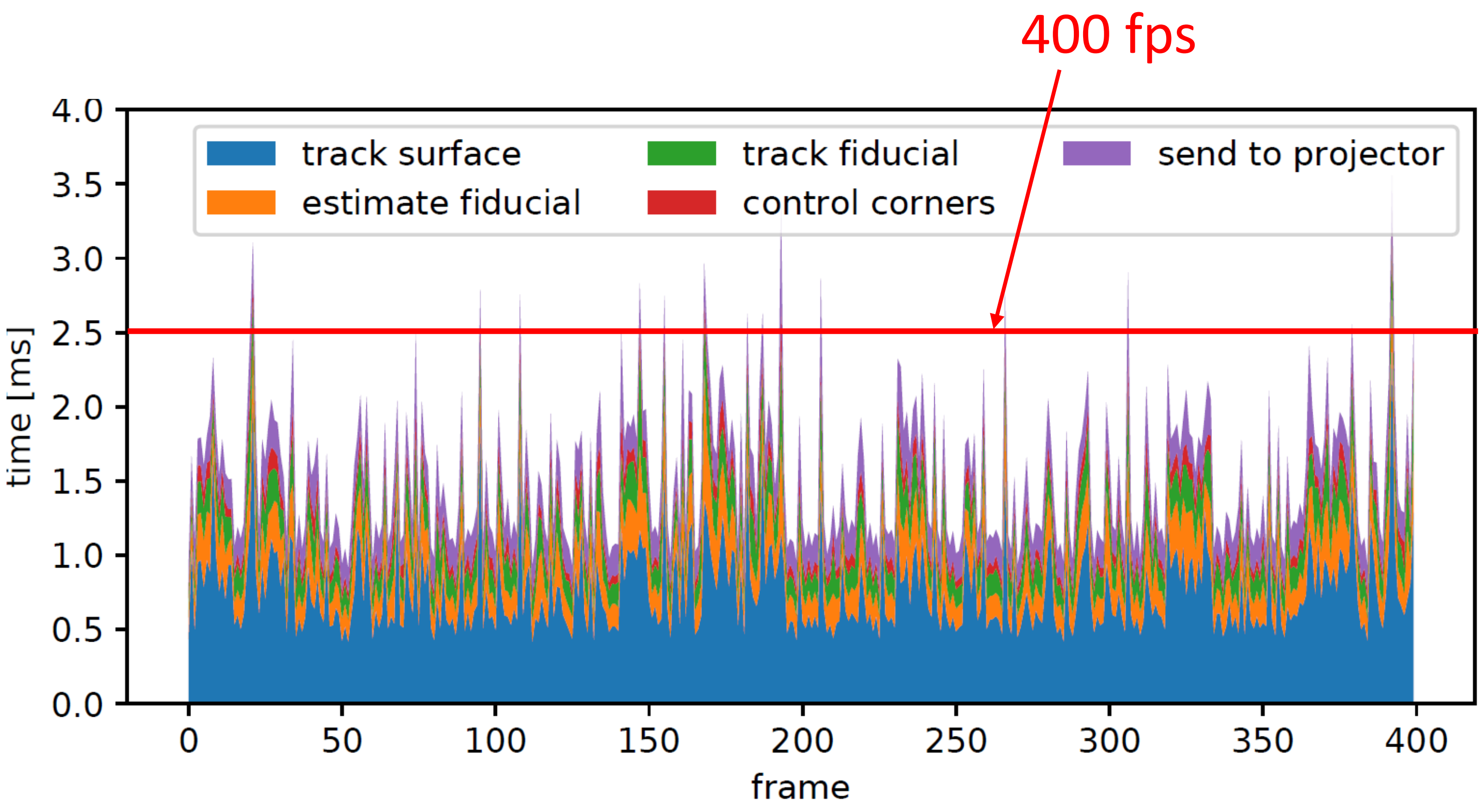
1024x768 DMD projector

- 2400 binary fps homography warping with Kintex-7 FPGA

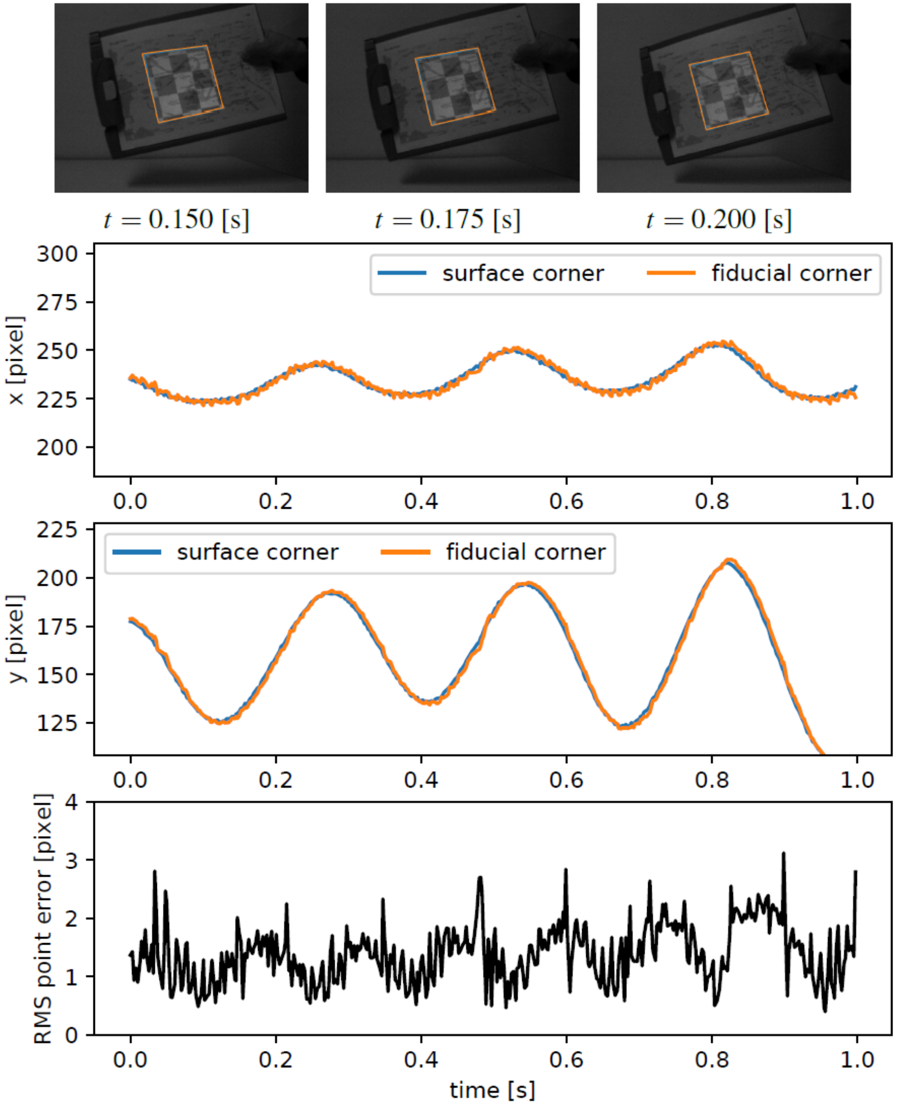
640x480 camera images

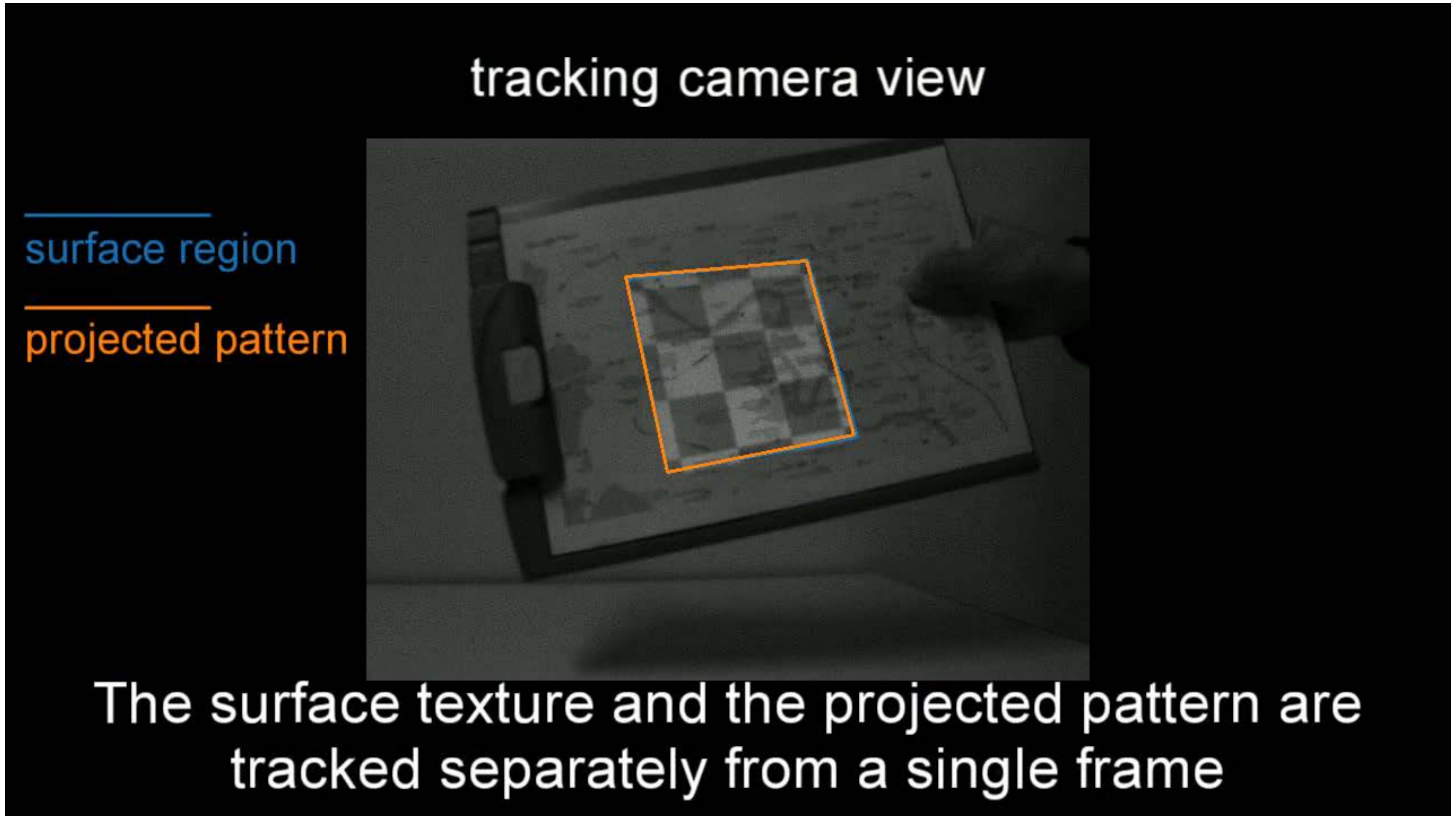
- 400 fps with Core i7-7600U
- ESM tracking algorithm (Benhimane+ IJRR 2007) optimized for Intel's SIMD instructions (Kagami+ SII 2016)

Proportional-Differential (PD) control of four control points with 1-step Smith predictor



Tracking Projection Performance





See the paper for quantitative off-line evaluation results

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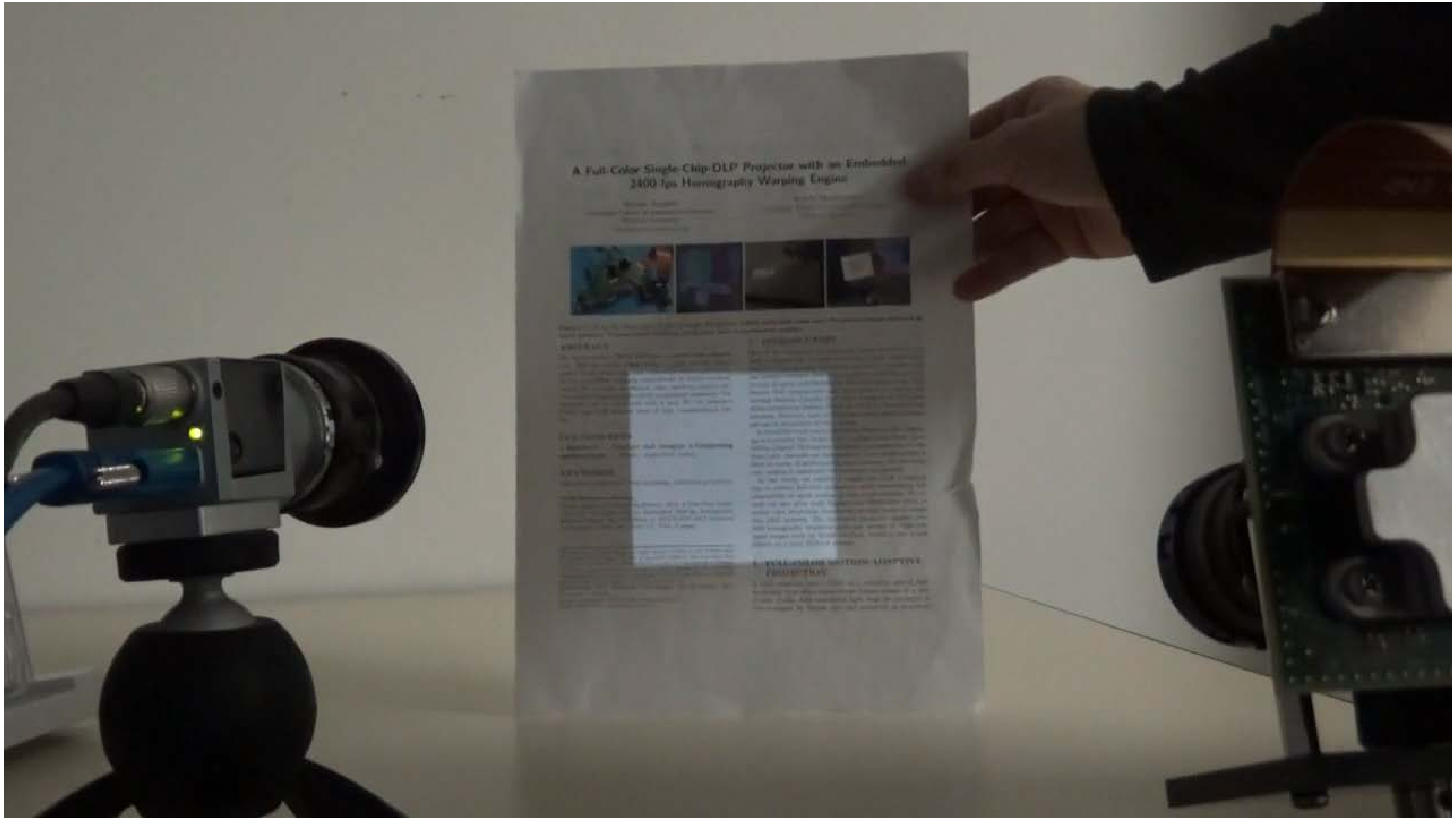
Miscellaneous Results



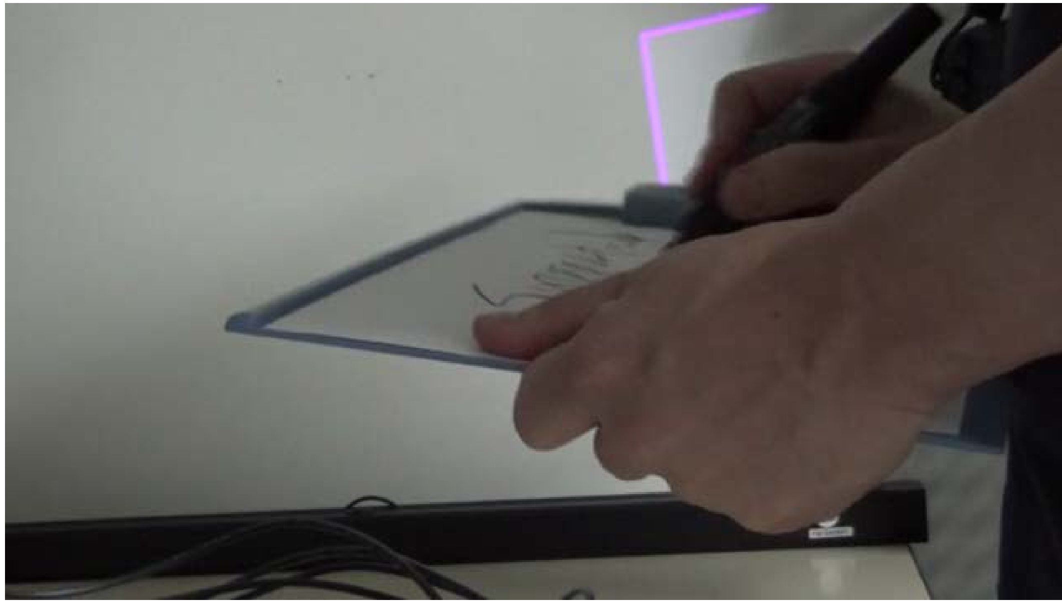
Limitations

- Contrast compromise of visible contents
  - common limitation with the “embedded code” approaches
- Dependency on surface texture
  - cannot track a solid-color surface
- Planar target only
  - will be tackled in future work
- Necessity of special low-latency projection hardware
  - …Yes, but we believe this is essential
  - Who imagined 20 years ago that a cell phone would be equipped with a high-speed camera?

Conclusions

- An approach to achieve a fast projection mapping of video content onto a markerless planar surface using an uncalibrated projector-camera pair is proposed
- A closed-loop alignment has been achieved by inserting fiducial patterns into the binary frame sequence of a DMD projector, which are designed to enable surface tracking and fiducial tracking simultaneously from a single camera image

Acknowledgment:



Demonstration #21 (Room 3, Oct 16-17, 10:00-17:30)

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