A FULL-COLOR SINGLE-CHIP-DLP PROJECTOR WITH AN EMBEDDED 2400-FPS HOMOGRAPHY WARPING ENGINE

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Photography & Recording Encouraged
MOTIVATION

Make every surface around you a display
- augmented-reality user interfaces
- media art installations
- stabilized projection by handheld projectors

Key Challenge:
- How to achieve low latency
SEE OUR E-TECH BOOTH

A FULL-COLOR SINGLE-CHIP-DLP PROJECTOR WITH AN EMBEDDED 2400-FPS HOMOGRAPHY WARping ENGINE

This installation presents a 24-bit full-color projector that achieves over 2400-fps motion adaptability using single-chip DLP technology, which will be useful for projection mapping applications in highly dynamic scenes. The projector can be interfaced with a host PC via standard HDMI and USB without the need of high computational burden.

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OUTLINE

• Motivation
• Low-Latency Vision and Projection
• Our Approach for Low-Latency Projection
• Hardware Implementation
• Color Representation
• Results
LOW-LATENCY VISION AND PROJECTION

• High-speed real-time-streaming cameras have already become commodity
• Lightweight fast visual processing algorithms are readily available

[Kagami+, SII2016]

• Then, what about projection?
DLP PROJECTORS

Digital Micromirror Devices (DMD)
- switches at up to tens of thousands of fps
- binary pattern is displayed at a time instant

http://www.dlp.com/jp/technology/how-dlp-works/
GRAY-LEVEL IMAGES COMPOSED OF BINARY PATTERNS

A number of binary patterns are time-integrated by human vision
HOW TO ACHIEVE HIGH FRAME RATE

• Combine with intensity modulation of light sources
• 8-bit monochrome image represented by (at least) 8 binary frames
• 3 times more for RGB color images
POSSIBLE APPROACHES FOR LOW-LATENCY MOTION-ADAPTIVE PROJECTION

✓ “normal” projectors can be used
X limited motion DoF
[Okumura+, ICME 2012]

✓ high versatility
X high data generation/transfer cost
[Watanabe+, IDW 2015]

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

______ input video

video frame time

motion command (e.g. rotation angle)

time

standard DLP representation (adapt to motion only at the video rate)

proposed approach (adapt to motion at the binary pattern rate)
WHAT HAPPENS IN THE OBSERVER’S EYES?

Direction of integration in time-space becomes changed
Low-latency DMD-based HMD:
- Maintain “ideal” target gray-level image at high rate
- Residual error image toward the “ideal” one is binarized and presented [Zheng+, ISMAR2014]
- Or, “ideal” image is binarized with random threshold [Lincoln+, TVCG 2016]

Microsoft Hololens:
- RGB color fields are sequentially post-warped by newest motion sensor readings [Klein, ISMAR2017 plenary]
- Decomposition into binary patterns does not take place (since LCoS is used)
HARDWARE IMPLEMENTATION

Our previous prototype [Kagami+, 2015]

Based on Texas Instruments DLP Discovery 4100
Non-modulated white LED

New prototype

Custom controller board
Intensity-modulated RGB LED
HARDWARE IMPLEMENTATION

USB -> Registers (homography matrix) -> DMD chipset
HDMI -> homography warping pipelines

video buffer
sequence inst.

SDRAM XILINX Kintex-7 FPGA (XC7K325T) LEDs and Drivers

video-rate input
stored in SDRAM storage or streamed via HDMI

output image

Homography warping parameters
(any perspective mapping from plane to plane)

2740 transforms/s for 1024x768 binary image
3-bit RGB with 21 binary patterns

- longer sequence needed for more bit depths

8-bit RGB with 24 binary patterns

- lower utilization of light
DESIGN TRADEOFFS

• binary pattern period:
  – should be short for more color depths with better light utilization
  – should be long for cheaper DMD employed or for small data bandwidth

• video frame period:
  – should be long for more color depths with better light utilization
  – should be short for quick motion adaptability, if video frame period equals to the unit time for motion adaptation
• With our approach, video frame period and unit time for motion adaptation are independent
• But the frame period should be short enough to avoid flicker perception
How 24-bpp color image is represented recognized as an external monitor by Windows PC
PROOF-OF-CONCEPT DEMO: TRACKING PROJECTION ONTO A MOVING SURFACE

Basler acA640-750 USB-3 camera (run at around 400 fps)

See [Kagami+, SIGGRAPH Asia 2015] for the detailed algorithm
PROOF-OF-CONCEPT DEMO: WARPED PROJECTION BY HAND GESTURE

Leap Motion sensor (run at around 200 fps)
SUMMARY

A full-color projector with low-latency motion adaptability
- per-bitplane warping approach
- color representation in single-chip-DLP configuration

Limitations
- Warping functions are hard-wired
- Brighter LEDs should be used for real applications

Future work
- Extending warping functions (e.g. for multiple polygons)
- User tests for image quality and latency perception

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