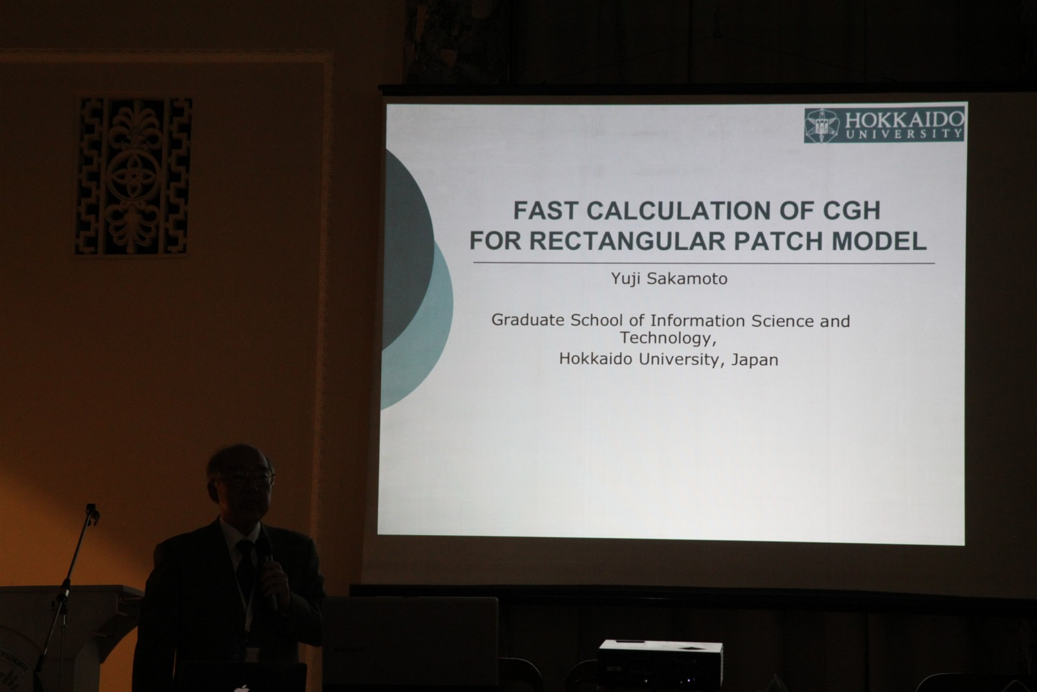
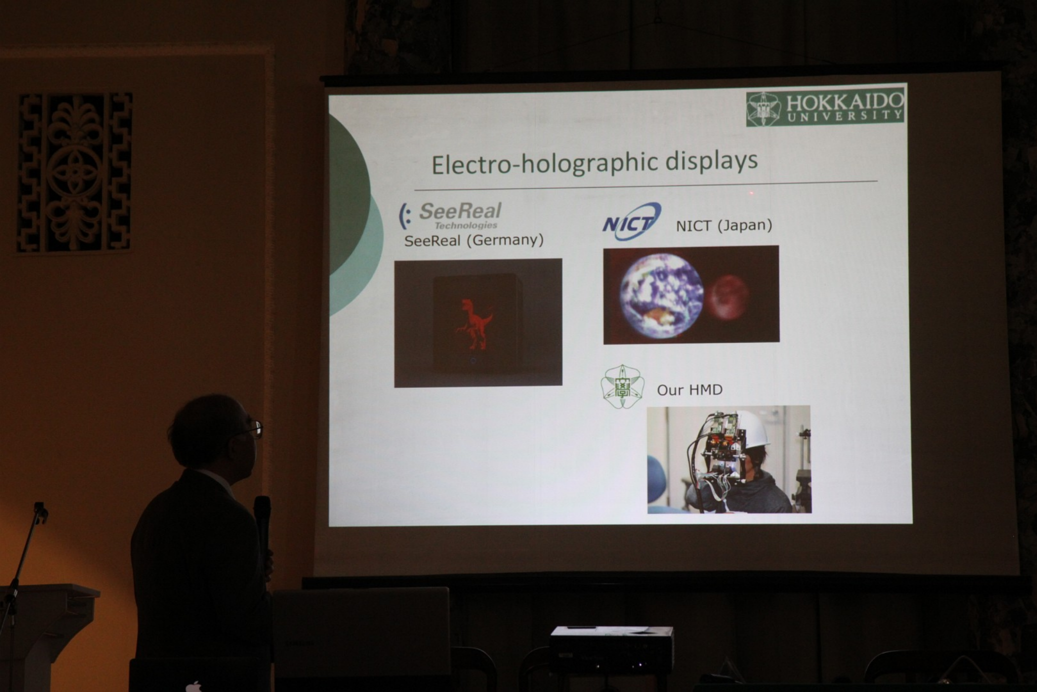
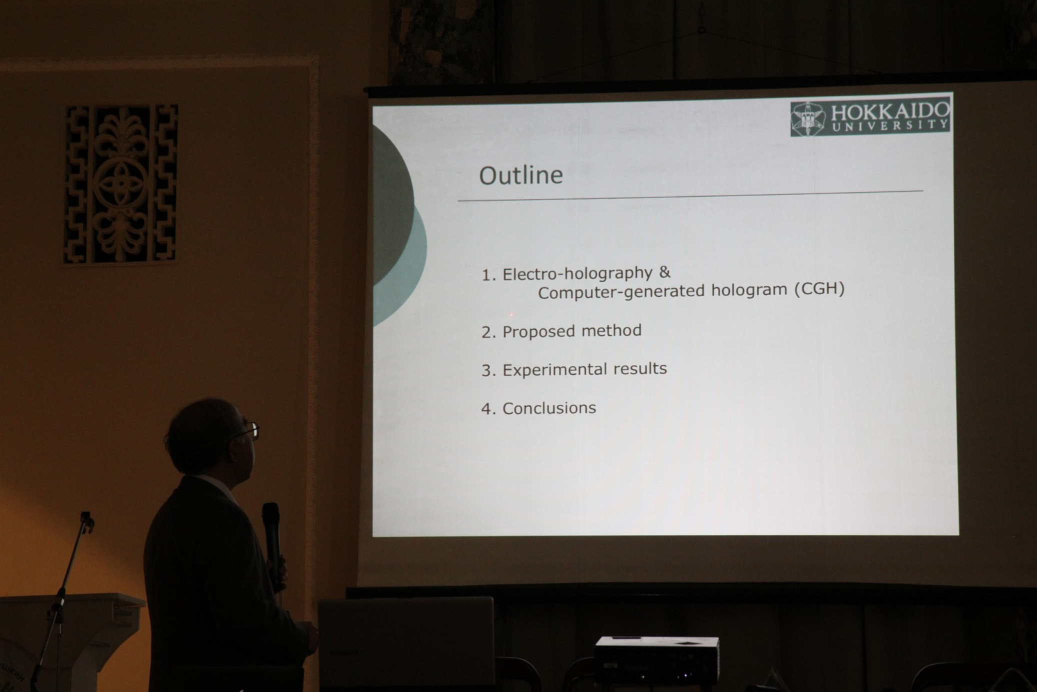
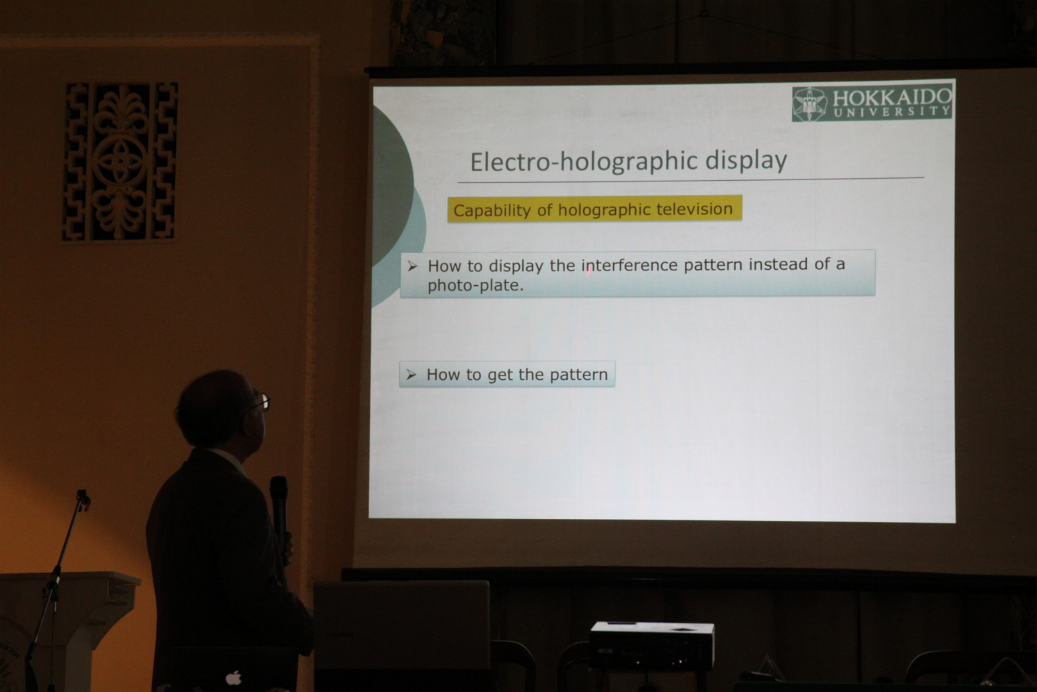
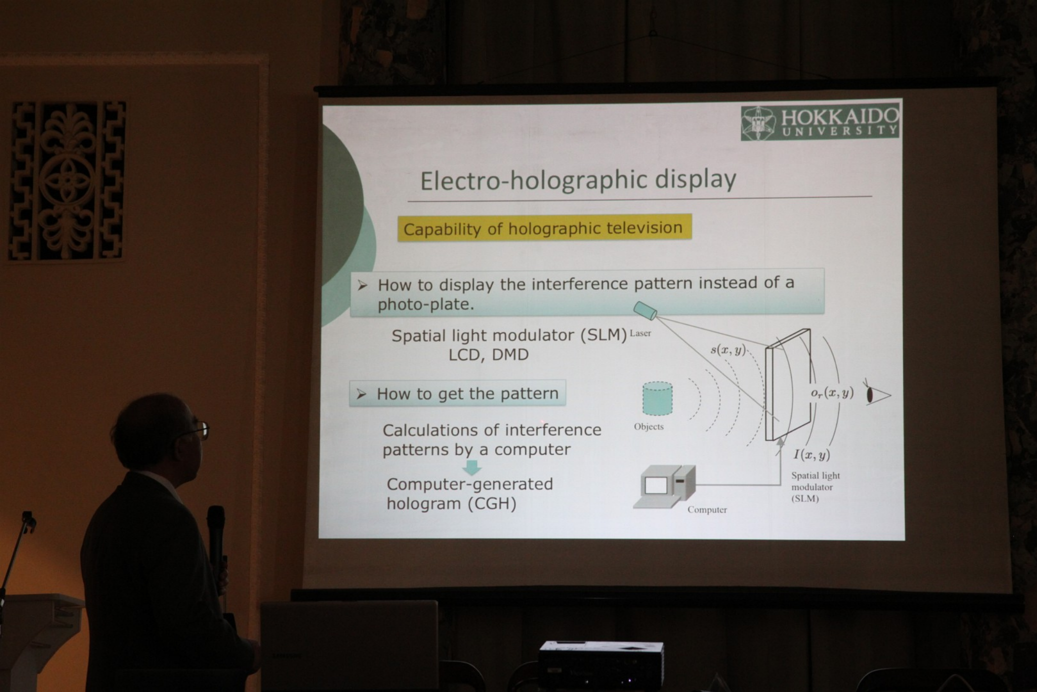
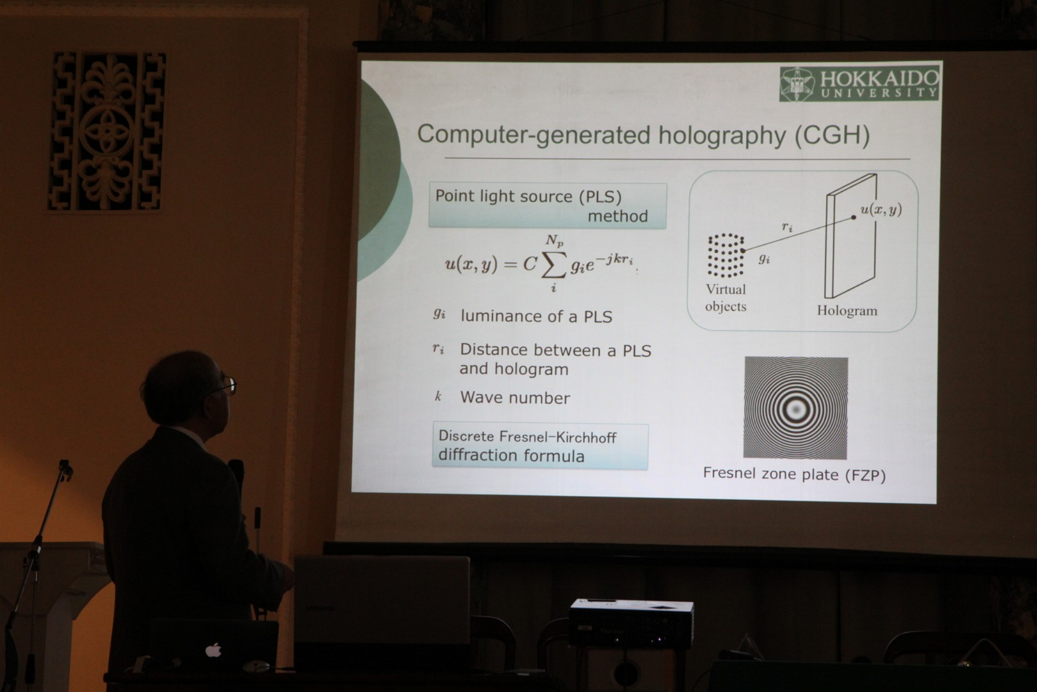

HOKKAIDO UNIVERSITY
FAST CALCULATION OF CGH
FOR RECTANGULAR PATCH MODEL
Yuji Sakamoto
Graduate School of Information Science and Technology,
Hokkaido University, Japan


HOKKAIDO
UNIVERSITY
Electro-holographic displays
SeeReal
Technologies
SeeReal (Germany)
NICT
NICT (Japan)
Our HMD


HOKKAIDO UNIVERSITY
Outline
1. Electro-holography &
Computer-generated hologram (CGH)
2. Proposed method
3. Experimental results
4. Conclusions


HOKKAIDO UNIVERSITY
Electro-holographic display
Capability of holographic television
➢ How to display the interference pattern instead of a photo-plate.
➢ How to get the pattern


HOKKAIDO UNIVERSITY
Electro-holographic display
Capability of holographic television
How to display the interference pattern instead of a photo-plate.
Spatial light modulator (SLM)
LCD, DMD
How to get the pattern
Calculations of interference patterns by a computer
Computer-generated hologram (CGH)
Laser
s(x, y)
Objects
o_r(x, y)
I(x, y)
Spatial light modulator (SLM)
Computer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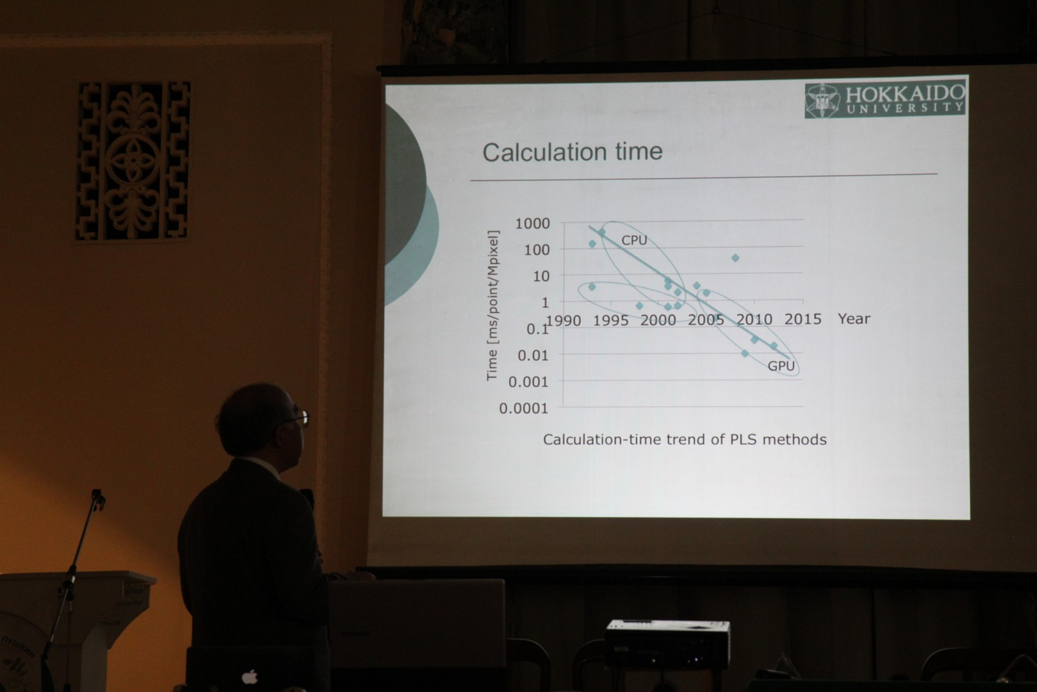
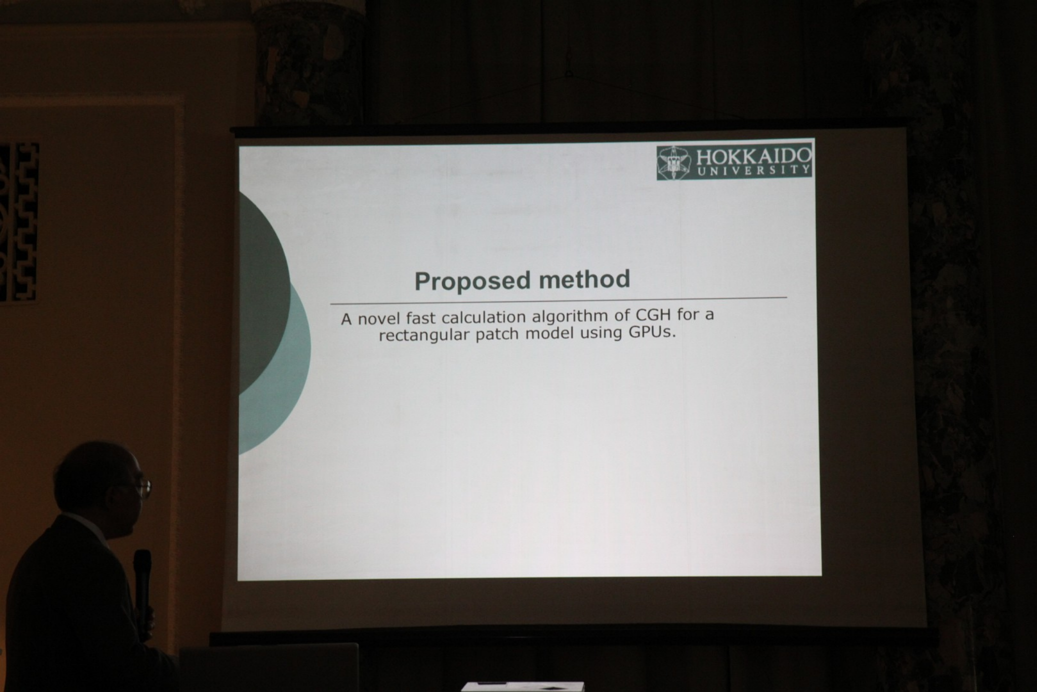
Computer-generated holography (CGH)
Point light source (PLS) method
$u(x,y) = C \sum_{i}^{N_p} g_i e^{-jkr_i}$
$g_i$ luminance of a PLS
$r_i$ Distance between a PLS and hologram
$k$ Wave number
Discrete Fresnel–Kirchhoff diffraction formula
$u(x,y)$
$r_i$
$g_i$
Virtual objects
Hologram
Fresnel zone plate (FZP)


HOKKAIDO UNIVERSITY
Calculation time
Time [ms/point/Mpixel]
1000
100
10
1
0.1
0.01
0.001
0.0001
1990 1995 2000 2005 2010 2015 Year
CPU
GPU
Calculation-time trend of PLS methods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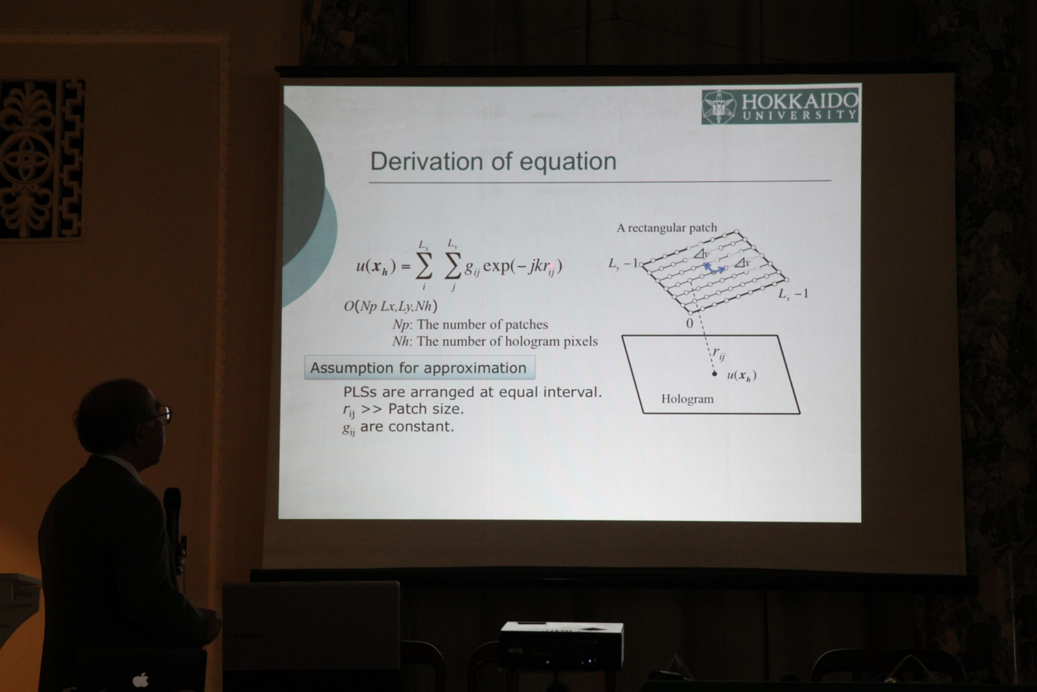
Proposed method
A novel fast calculation algorithm of CGH for a rectangular patch model using GPUs.



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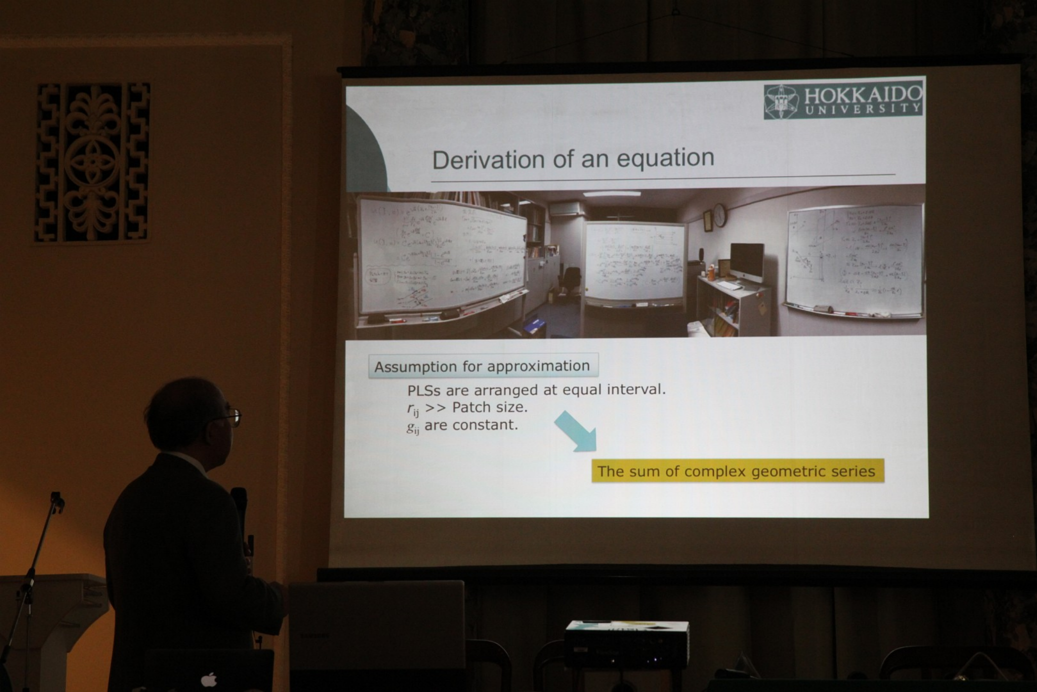
Derivation of equation
$u(\boldsymbol{x}_h) = \sum_{i}^{L_x} \sum_{j}^{L_y} g_{ij} \exp(-jkr_{ij})$
$O(Np\ Lx, Ly, Nh)$
$Np$: The number of patches
$Nh$: The number of hologram pixels
Assumption for approximation
PLSs are arranged at equal interval.
$r_{ij}$ >> Patch size.
$g_{ij}$ are constant.
A rectangular patch
$L_y - 1$
$\Delta y$
$\Delta x$
$L_x - 1$
0
$r_{ij}$
$u(\boldsymbol{x}_h)$
Hologram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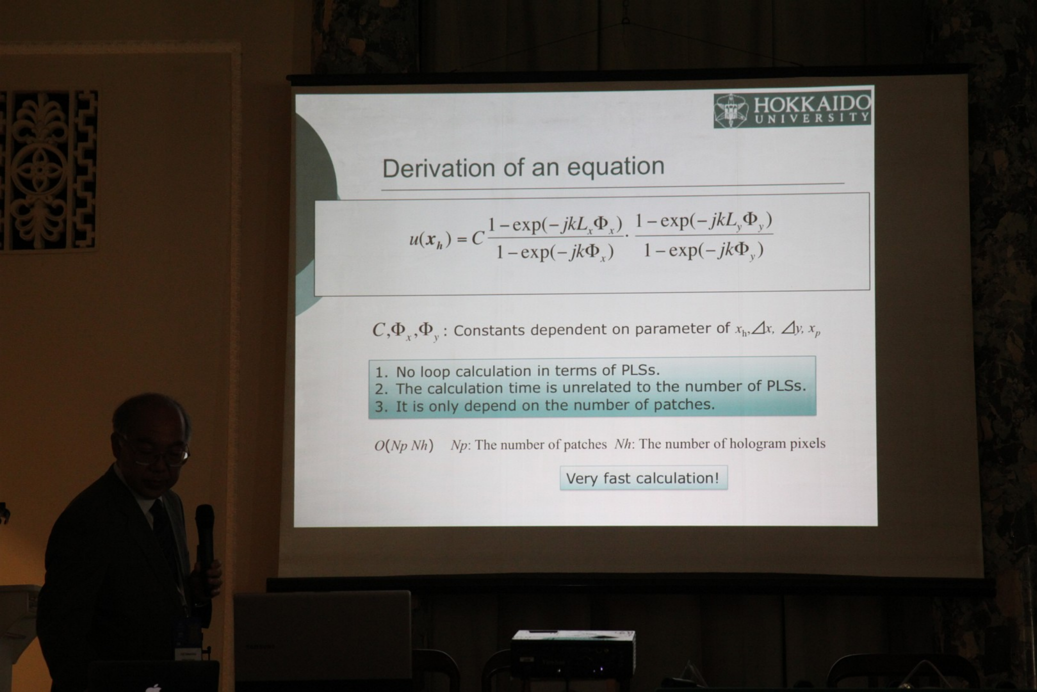
Derivation of an equation
Assumption for approximation
PLSs are arranged at equal interval.
$r_{ij}$ >> Patch size.
$g_{ij}$ are constant.
The sum of complex geometric series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Derivation of an equation
$$u(\boldsymbol{x}_h) = C\frac{1-\exp(-jkL_x\Phi_x)}{1-\exp(-jk\Phi_x)}\cdot\frac{1-\exp(-jkL_y\Phi_y)}{1-\exp(-jk\Phi_y)}$$
$C, \Phi_x, \Phi_y$ : Constants dependent on parameter of $x_h$, $\Delta x$, $\Delta y$, $x_p$
1. No loop calculation in terms of PLSs.
2. The calculation time is unrelated to the number of PLSs.
3. It is only depend on the number of patches.
$O(Np\ Nh)$ $Np$: The number of patches $Nh$: The number of hologram pixels
Very fast calculation!


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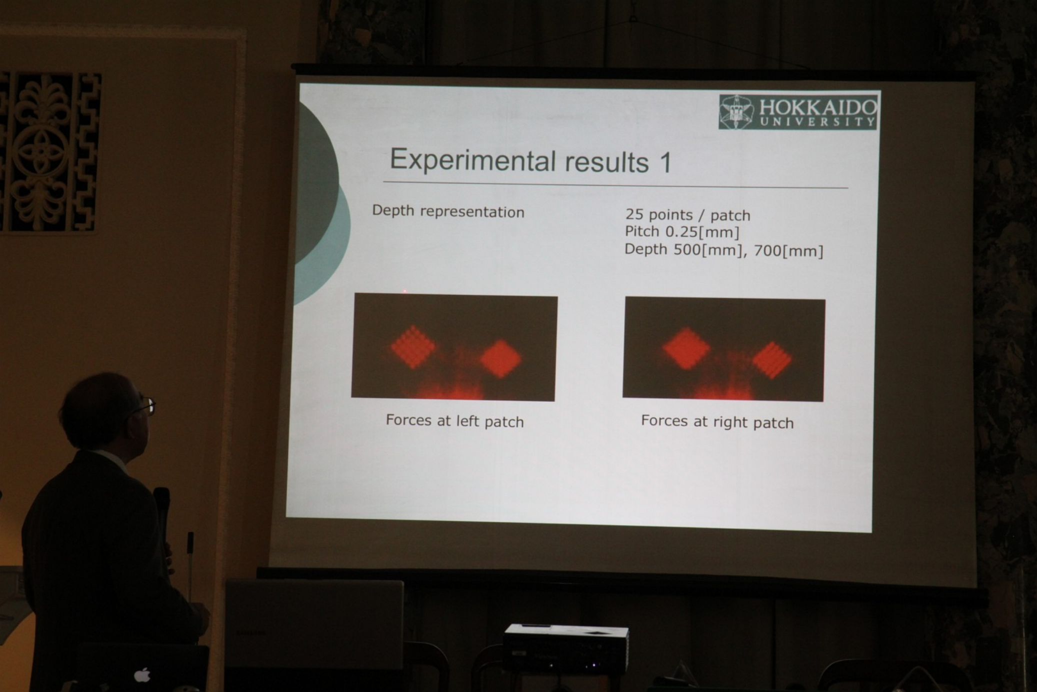
Experimental results
Does the equation work well?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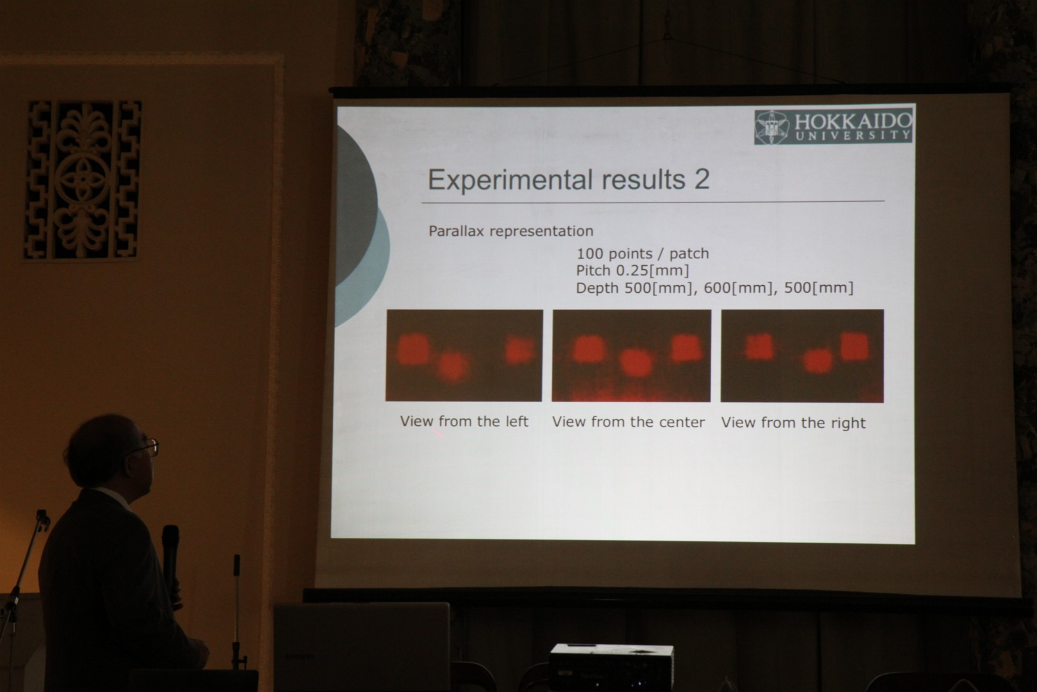
Experimental results 1
Depth representation
25 points / patch
Pitch 0.25[mm]
Depth 500[mm], 700[mm]
Forces at left patch
Forces at right patch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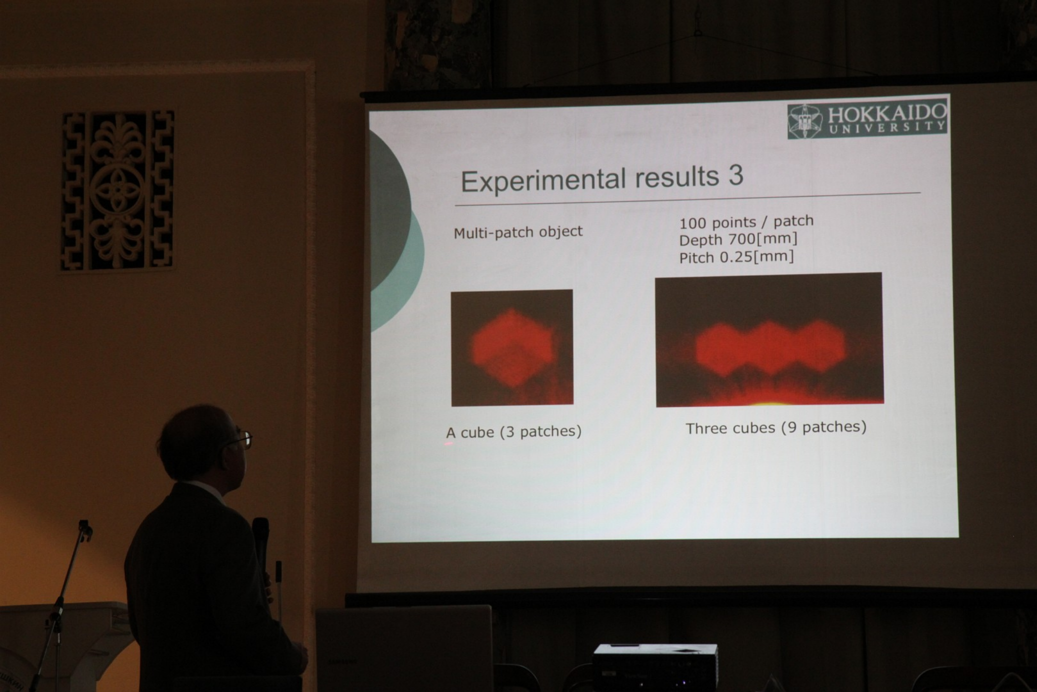
Experimental results 2
Parallax representation
100 points / patch
Pitch 0.25[mm]
Depth 500[mm], 600[mm], 500[mm]
View from the left
View from the center
View from the right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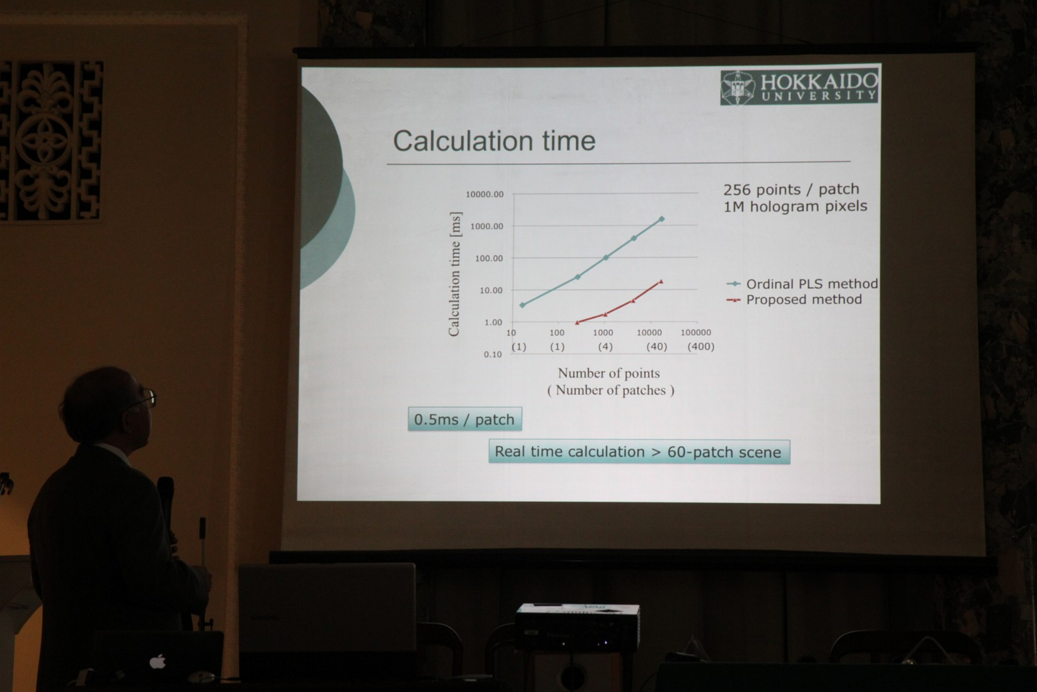
Experimental results 3
Multi-patch object
100 points / patch
Depth 700[mm]
Pitch 0.25[mm]
A cube (3 patches)
Three cubes (9 patches)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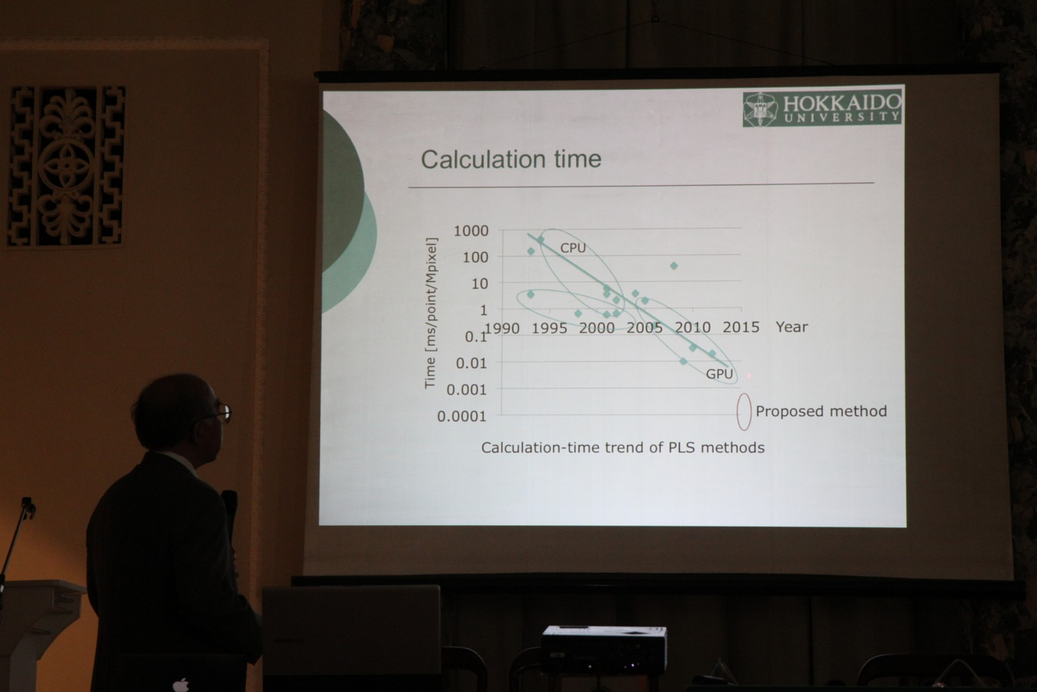
Calculation time
256 points / patch
1M hologram pixels
10000.00
1000.00
100.00
10.00
1.00
0.10
Calculation time [ms]
10
100
1000
10000
100000
(1)
(1)
(4)
(40)
(400)
Number of points
( Number of patches )
Ordinal PLS method
Proposed method
0.5ms / patch
Real time calculation > 60-patch scene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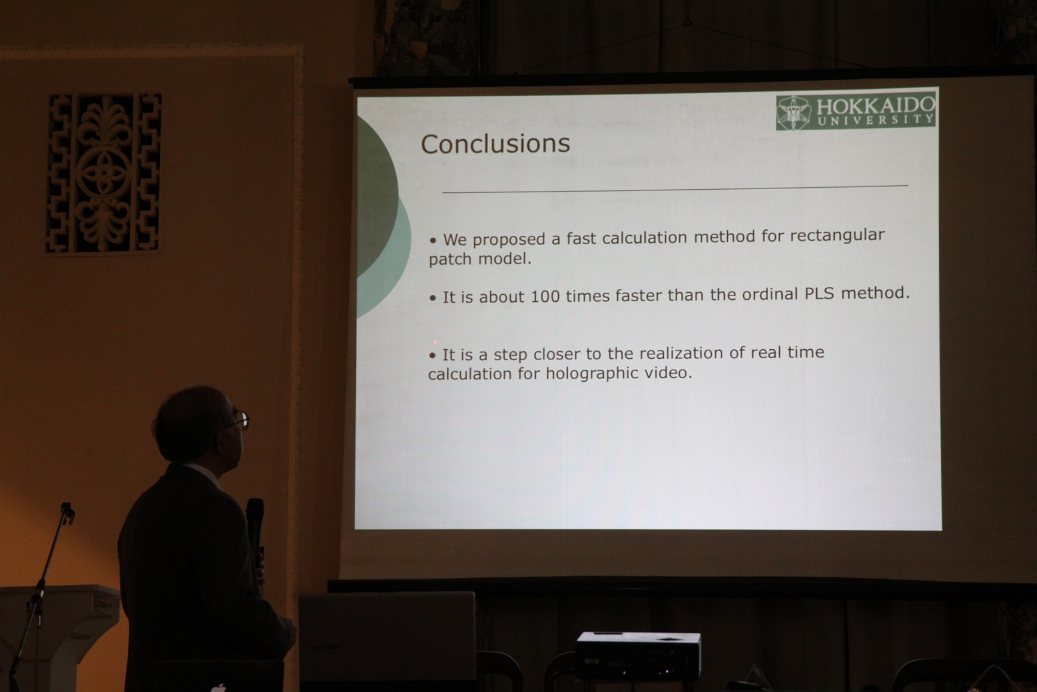
Calculation time
1000
100
10
1
0.1
0.01
0.001
0.0001
Time [ms/point/Mpixel]
1990 1995 2000 2005 2010 2015 Year
CPU
GPU
Proposed method
Calculation-time trend of PLS methods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Conclusions
• We proposed a fast calculation method for rectangular patch model.
• It is about 100 times faster than the ordinal PLS method.
• It is a step closer to the realization of real time calculation for holographic video.


Thank you for your kind attention.
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