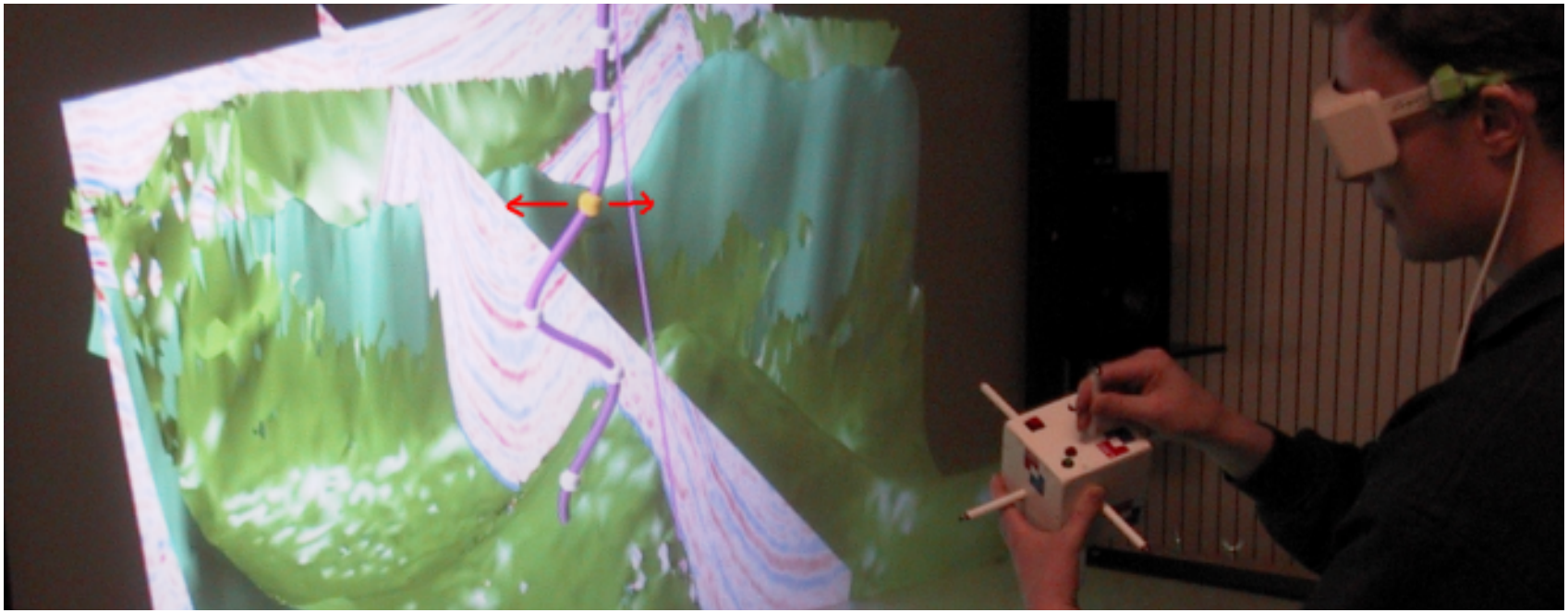
Multi-Frame Rate Rendering and Display

Jan P. Springer[1] Stephan Beck[1] Felix Weiszig[1]

Dirk Reiners[2] Bernd Froehlich[1]

[1] Bauhaus-Universität Weimar [2] University of Louisiana at Lafayette

Observations for Complex Applications



High frame rates:

- Object manipulation
- System control

Low(er) frame rates:

- Head tracking
- Navigation

Multi-Frame Rate Rendering and Display

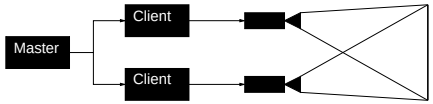
Asynchronous rendering

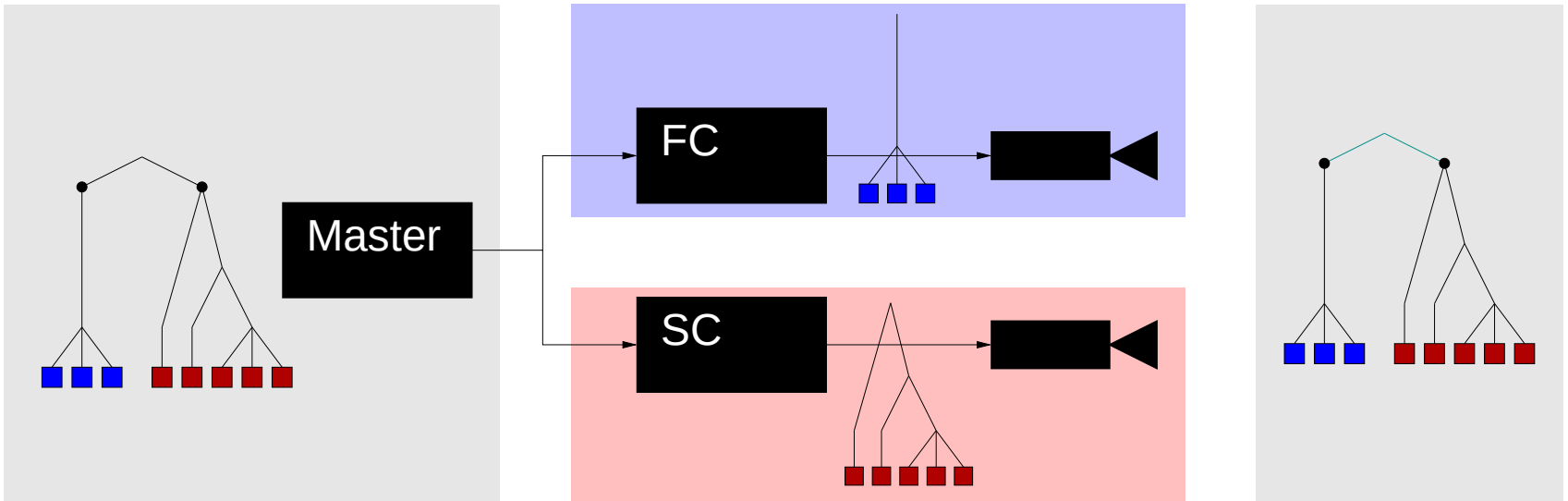
- Distribute scene to two clients (graphics cards / computers)
- Fast client will render:
  - manipulated/active objects
  - system control
- Slow client will render:
  - rest of the scene

Results combined into multi-frame rate display

- Optical superposition
- Digital composition

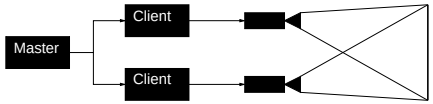
Optical Superposition

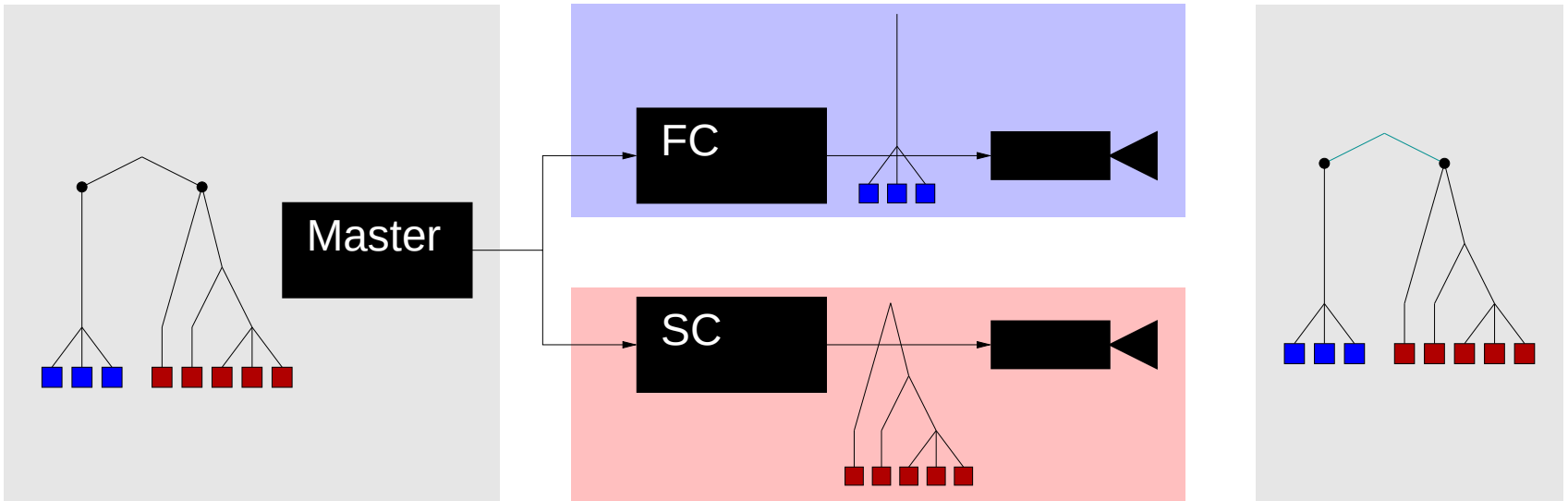




Inspired by Majumder and Welch, *Compter Graphics Optique: Optical Superposition of Projected Computer Graphics*, IPT - EGVE 2001

Optical Superposition





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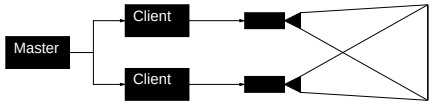
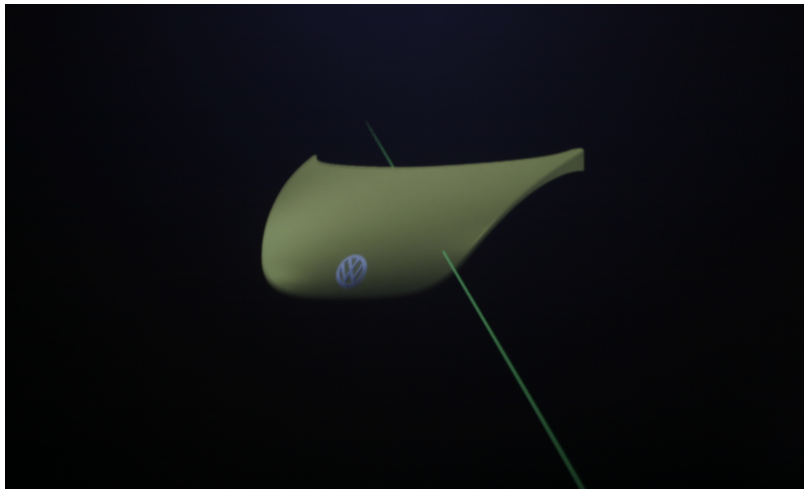


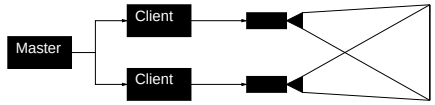
Slow client (SC)

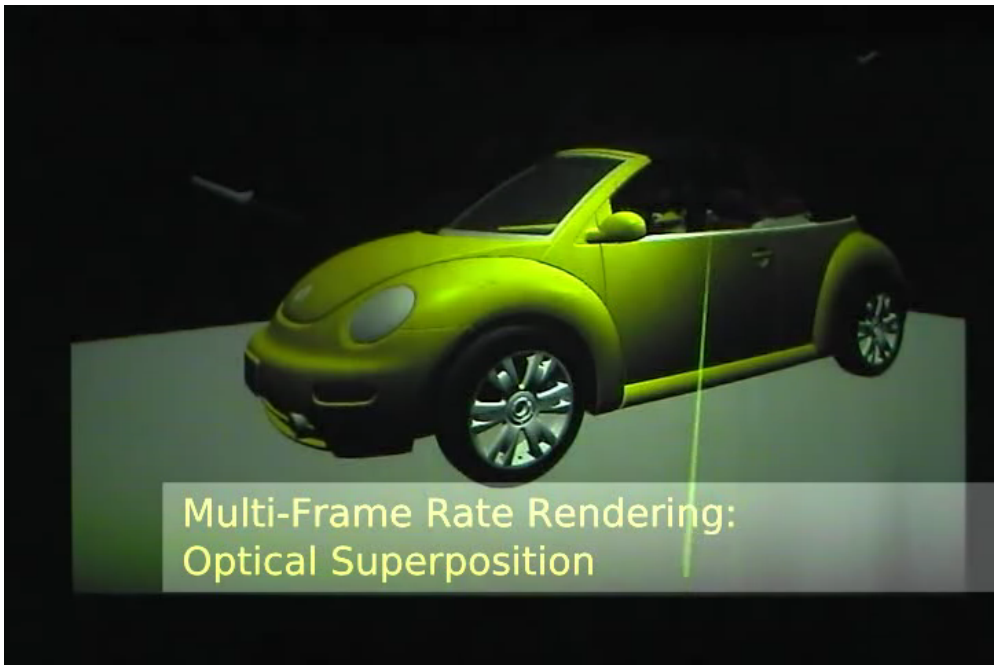


Fast client (FC)

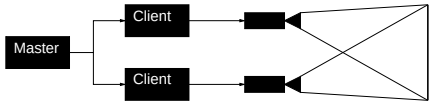
Optically combined image on display

Optical Superposition





Optical Superposition

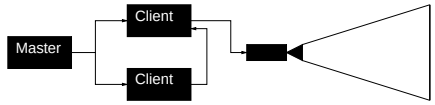


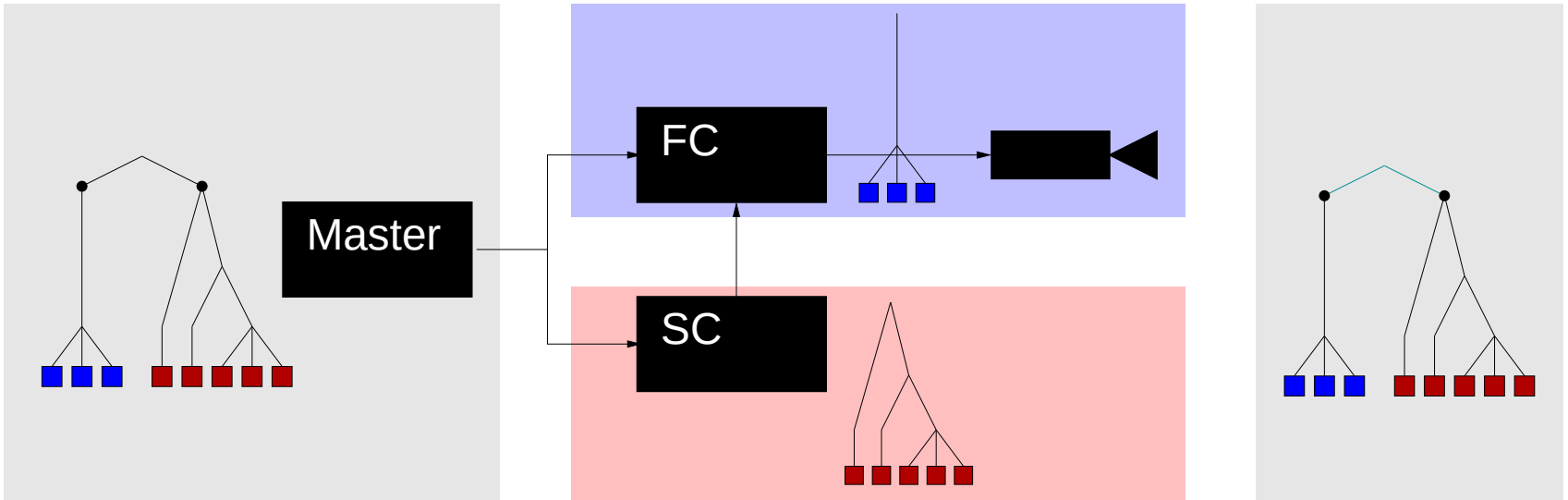
Properties and issues

+ Easy to implement
+ Fast interaction and object manipulation

– No occlusion between objects on fast and slow client
– Half transparency for overlapping objects from FC and SC
– Popping artifacts during selection and deselection of objects
– Requires 2 × number of projectors

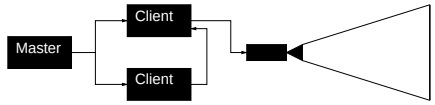
Digital Composition

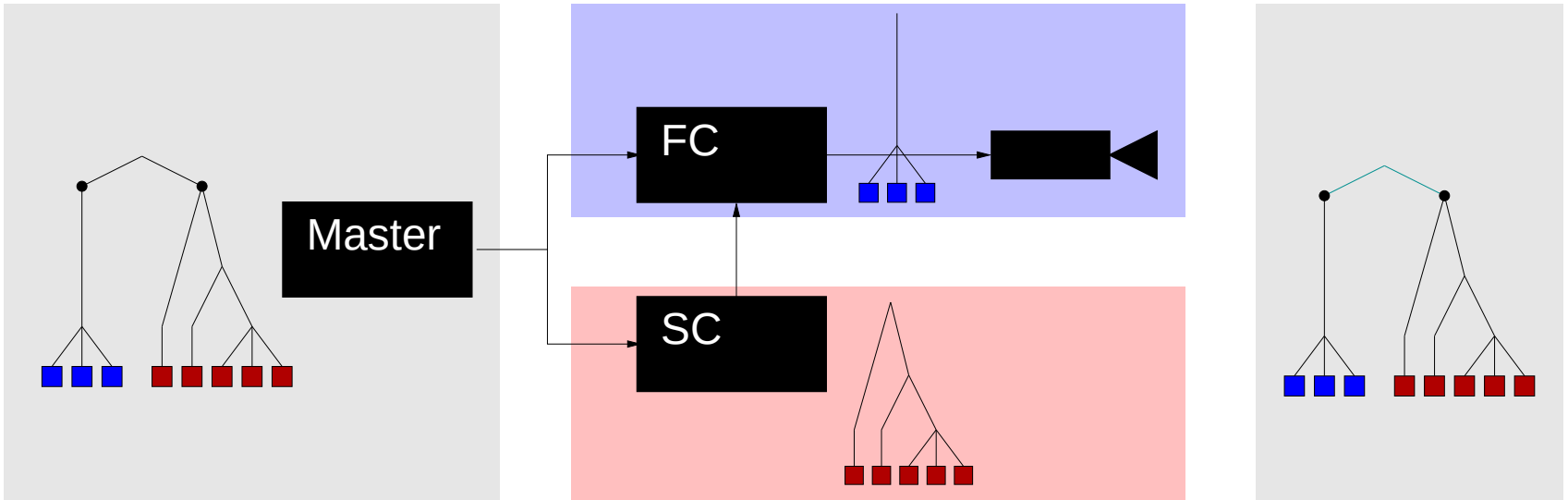




Inspired by Sort-Last parallel graphics

Digital Composition





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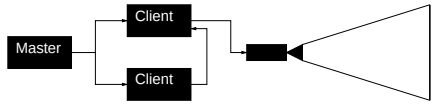
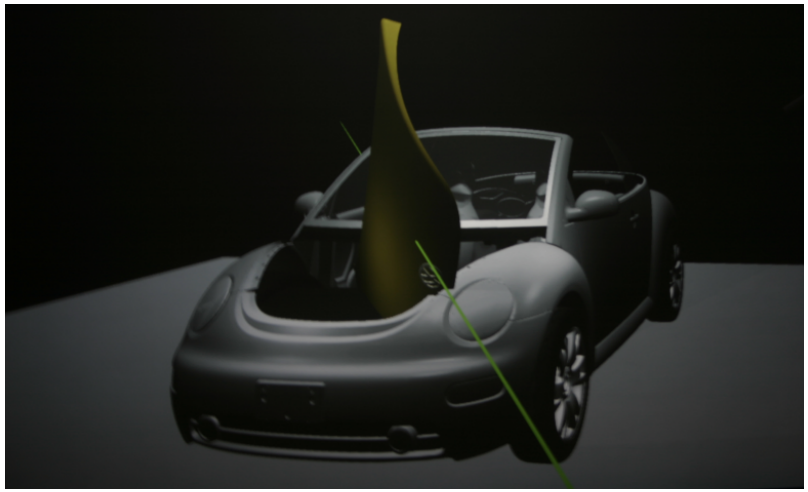
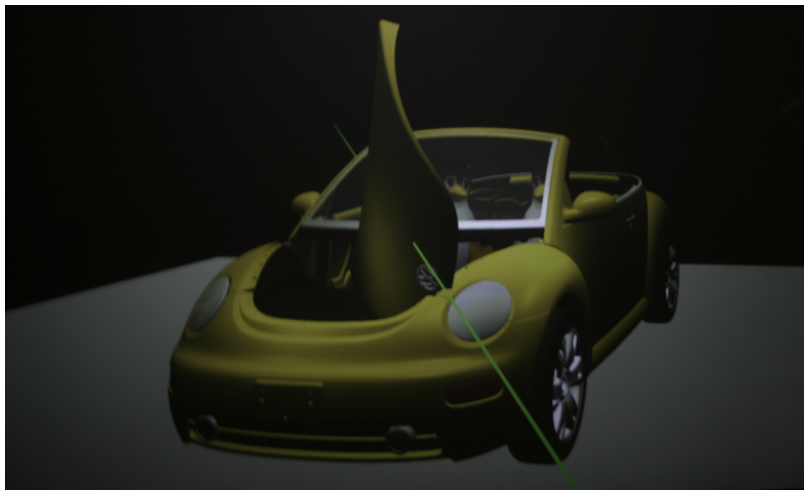


Slow client

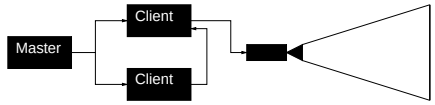


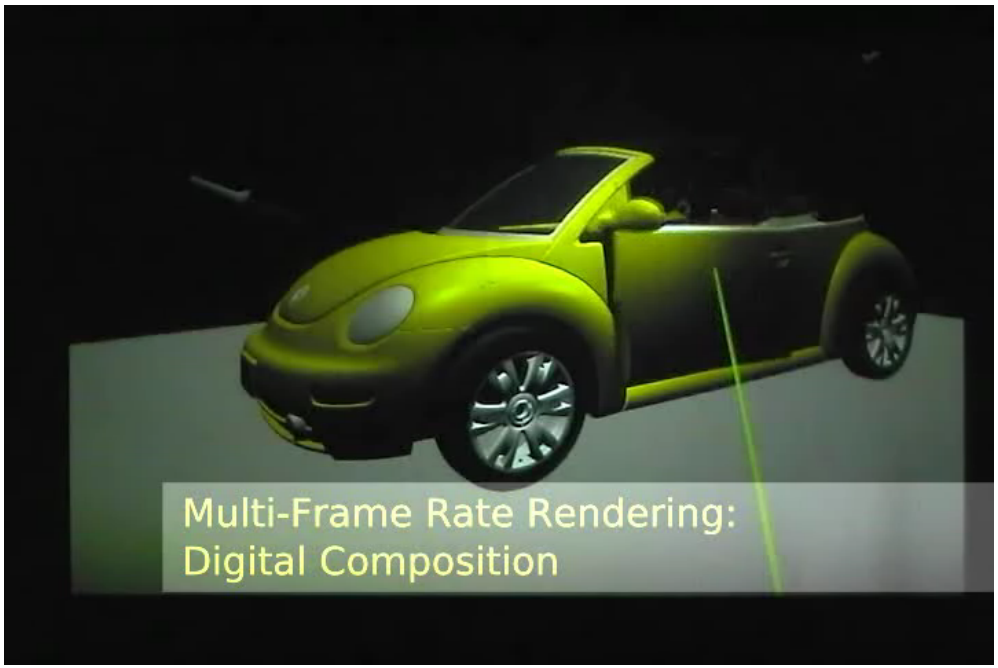
Fast client



Digitally composited image on display

Digital Composition





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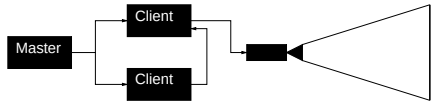


Properties and issues

+ Fast interaction and object manipulation
+ Perfect occlusion between objects on fast and slow client

– Implementation more difficult
  - Transfer of depth/color buffer from SC to FC
  - Transfer of view transform from SC to FC
– Popping artifacts during selection and deselection of objects
– Increased latency for images generated by SC
– Network limits update rates of SC

User Study

Hypothesis

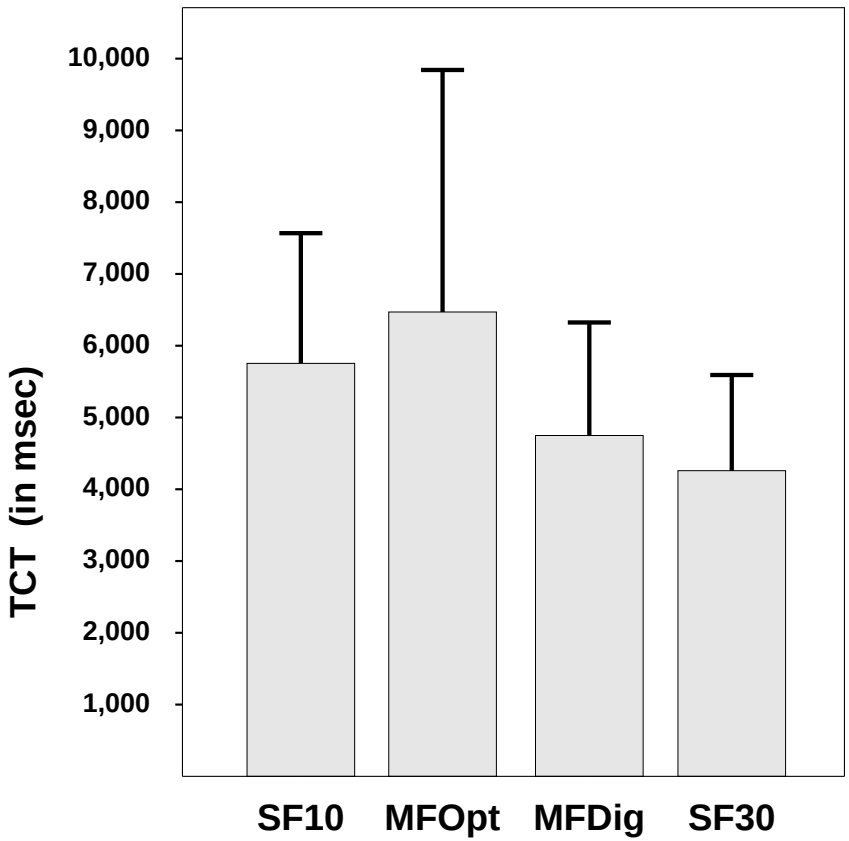
Digital or optical multi-frame rate method improves interaction performance with respect to single-frame rate method at low frame rates

Experiment Setup

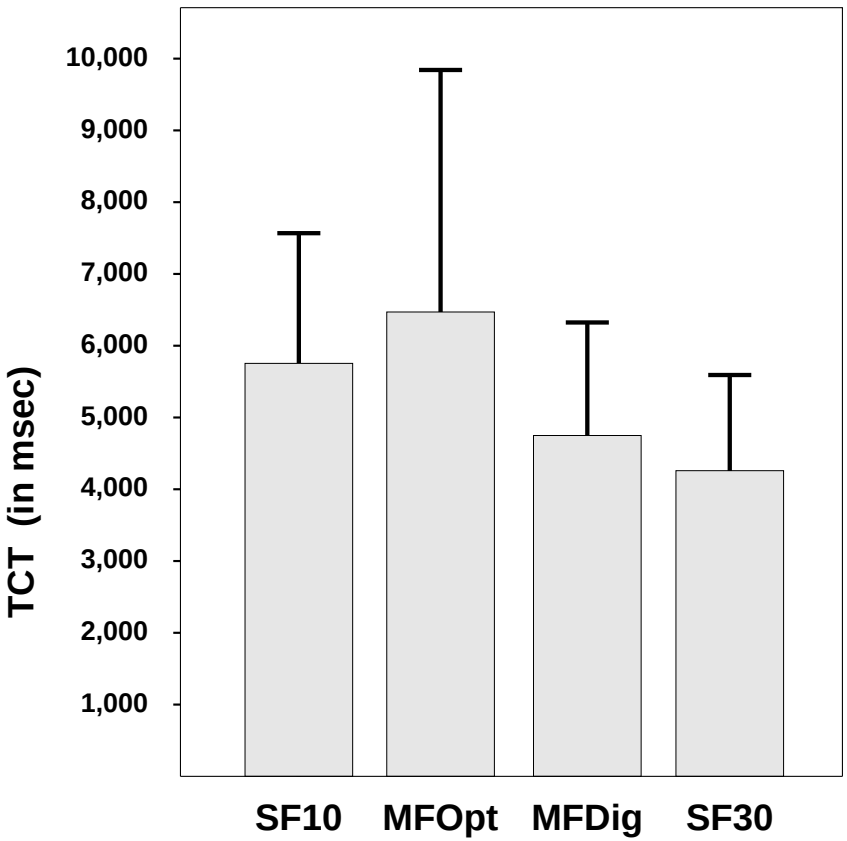
- Basic 3 DOF docking task, head tracked, 16 participants
- Render methods:
  - single-frame rate @ 10 Hz (SF_{10})
  - multi-frame rate w/ optical superposition @ 10/30 Hz (MF_{opt})
  - multi-frame rate w/ digital composition @ 10/30 Hz (MF_{dig})
  - single-frame rate @ 30 Hz (SF_{30})
- Measure task completion times (TCT)
- Determine user preference (scale from 1 to 5)

Experiment Setup

Results


10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
TCT (in msec)
SF10
MFOpt
MFDig
SF30

Results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10,000
9,000
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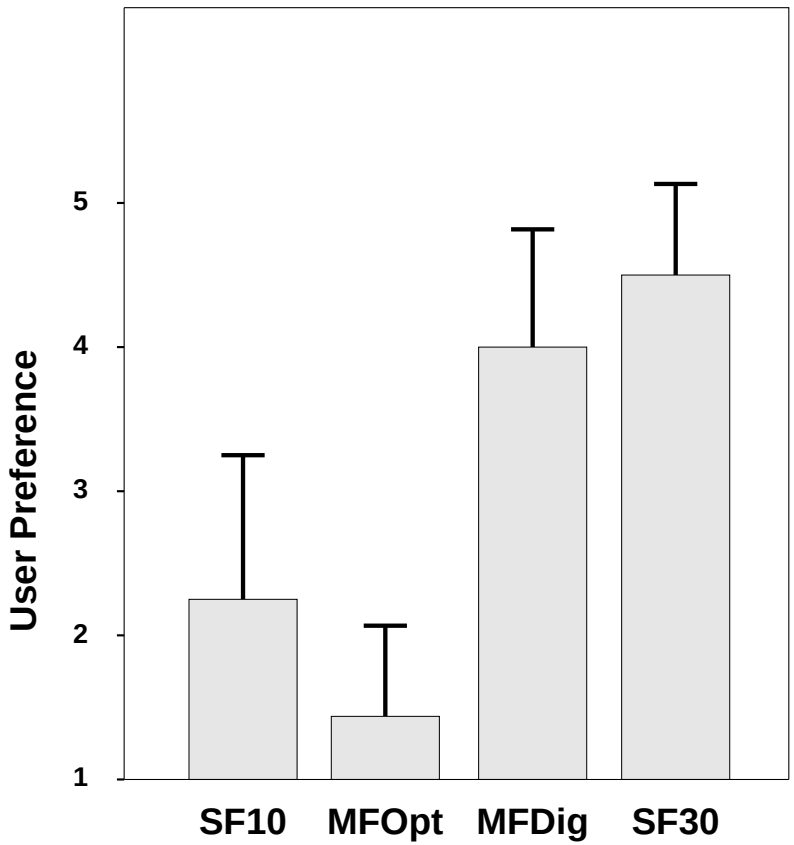

User Preference
5
4
3
2
1
SF10
MFOpt
MFDig
SF30

Discussion: Artifacts

- Popping at selection
- Popping at deselection
- Transparency
- Manipulation effecting the whole scene (e. g. moving a light source)

Discussion: End-to-End Latency

- Optical superposition
  No additional latency

- Digital composition
  $T_{\text{Read Color/Depth on SC}} + T_{\text{Send over Network}} + T_{\text{Draw Color/Depth on FC}}$

End-to-End Latency: Graphics

		1280×1024		1600×1200	
		MB/s	ms	MB/s	ms
Read	BGRA_EXT	997	5.3	939	8.4
	DEPTH	565	9.3	733	10.8
Draw	BGRA_EXT	2081	2.5	2166	3.6
	DEPTH	1213	4.3	1372	5.7

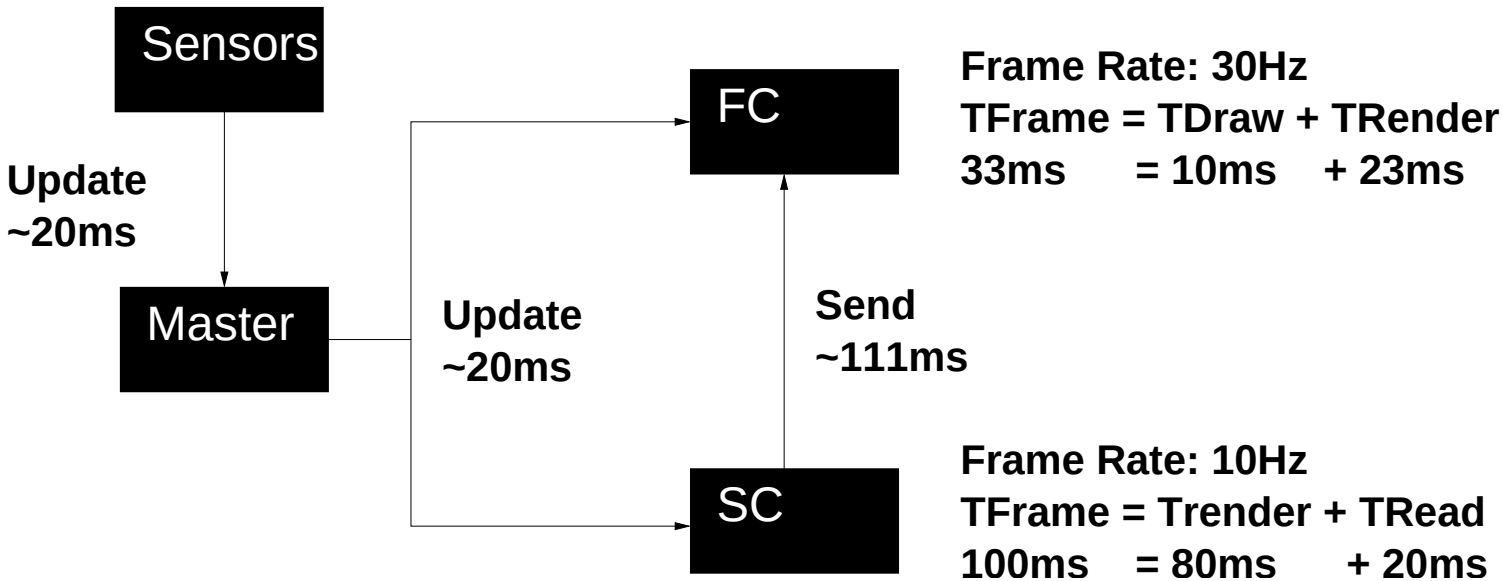
- nVidia GeForce 8800 GTX, driver rev. 97.46
- Note: selecting the "right" color format makes a difference

End-to-End Latency: Network

Resolution 64 Bit Color/Depth	Packet Size in MBytes	Transfer Time in ms
1024×768 @ 15 Hz	6	66
1280×1024 @ 9 Hz	10	111
1600×1200 @ 6 Hz	15	166

- Assuming 90 Mbytes/s bandwidth

End-to-End Latency: Example

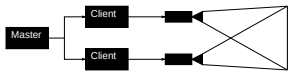


- Resolution: 1280×1024
- Compression may not decrease network latency
  see Roth and Reiners, *Sorted Pipeline Image Composition*, EGPGV06

Summary

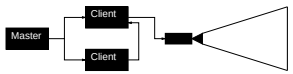
- Multi-frame rate rendering
  - Improves object manipulation and system control
  - Does not improve navigation
  - Works with stereo and head tracking

- Optical superposition



  - Composition artifacts (half-transparency, popping)
  - Precise manipulation very difficult
  - Useful for system control and foreground elements

- Digital composition



  - Few artifacts — most can be fixed
  - Artifacts may not be noticed
  - Requires **very** fast network (e. g. 10 GBit)
  - User study confirms performance almost as good as rendering everything fast

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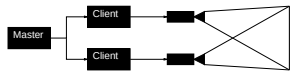

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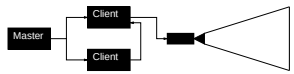

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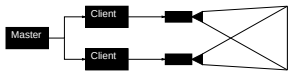

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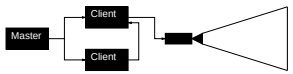

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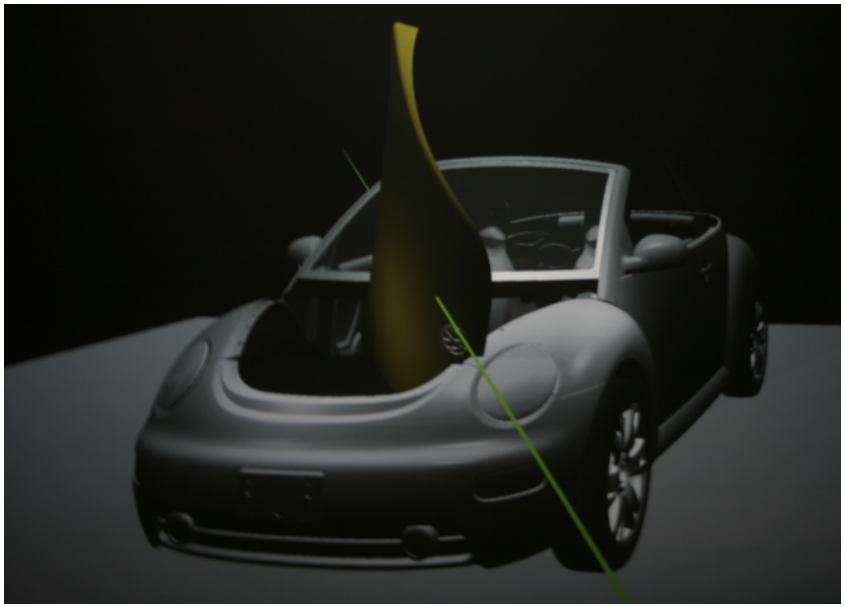
Future Work

- Refine digital composition approach
  - Transfer screen rectangle of selected object for non-tracked scenarios
  - Implement popping artifact fixes
  - Transparency artifact solution for special cases (e. g. volume rendering)
  - Evaluate on multi-GPU system
- Further user studies
  - Lowest limit for head tracking update rates?
  - Which frame rate ratios for SC and FC work well?
- Combine with other parallel rendering strategies
  - Resource (re-)allocation/balancing

Thank you for your attention.



IPT - EGVE 2007

Weimar, Germany

- Submission deadline:
  March 31, 2007
- Conference:
  July 15 – 18, 2007

http://www.uni-weimar.de/medien/vr/ipt-egve