Visualizing Large Image Datasets in 3D Using WebGL and Media Fragments

Overview

- Introduction
  - WebGL
  - Media Fragments
  - Virtual Texturing
- System Overview
  - Determining the working set
  - Page table generation
  - Page requests
  - Server Side
- Results
- Conclusions

WebGL

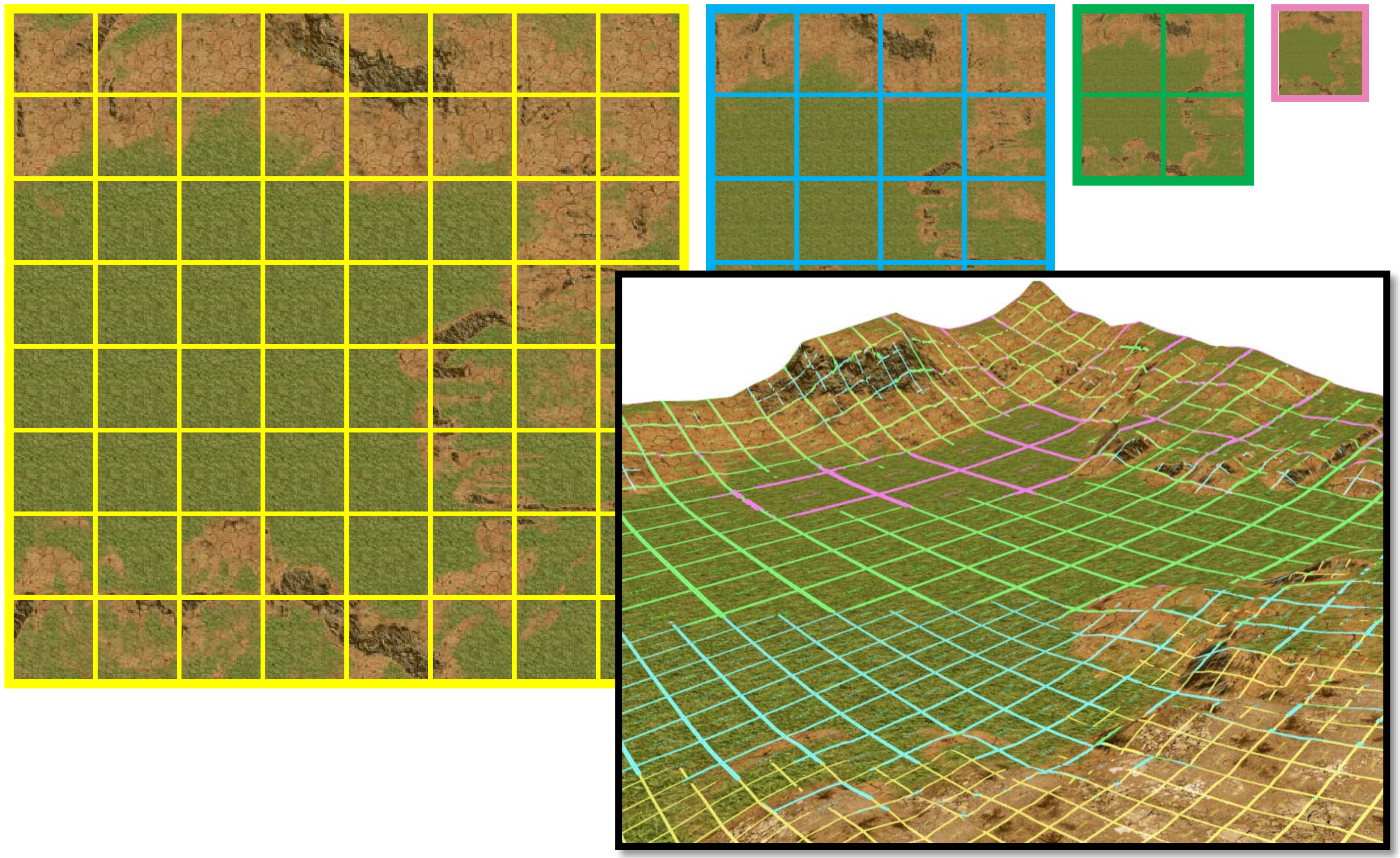
- Spec. is v1.0 since 10/2/2011
- OpenGL ES 2.0 binding for HTML5 browsers
  - Shaders, render to texture, …
- Extra limitations to ensure security
- Based on the canvas element
- Additional supporting classes and objects
  - Typed arrays: Int32Array, Float32Array, …
- Browser support status:

Chrome	Firefox	Safari	Opera	Ie
Live	Live	Nightlies	v11 Prev.	Plugin

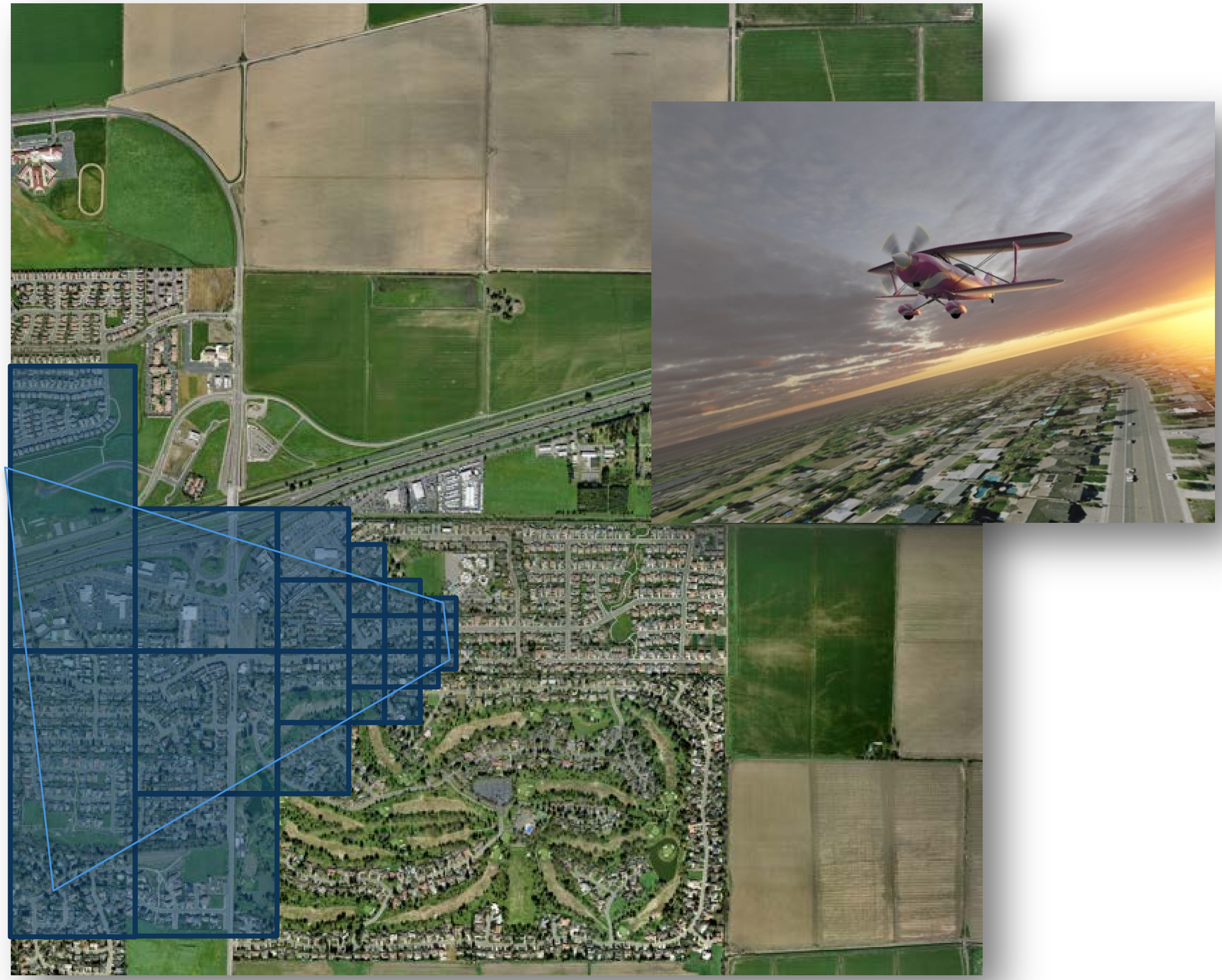
Media Fragments

- Media-format independent, standard means of addressing media fragments on the Web using URIs
- Allows addressing
  - Time in audio/video
  - 2D Spatial regions
  - Different content channels
- Two formats
  - URI fragments: media.mkv#track=1
  - URI queries: media.mkv?track=1

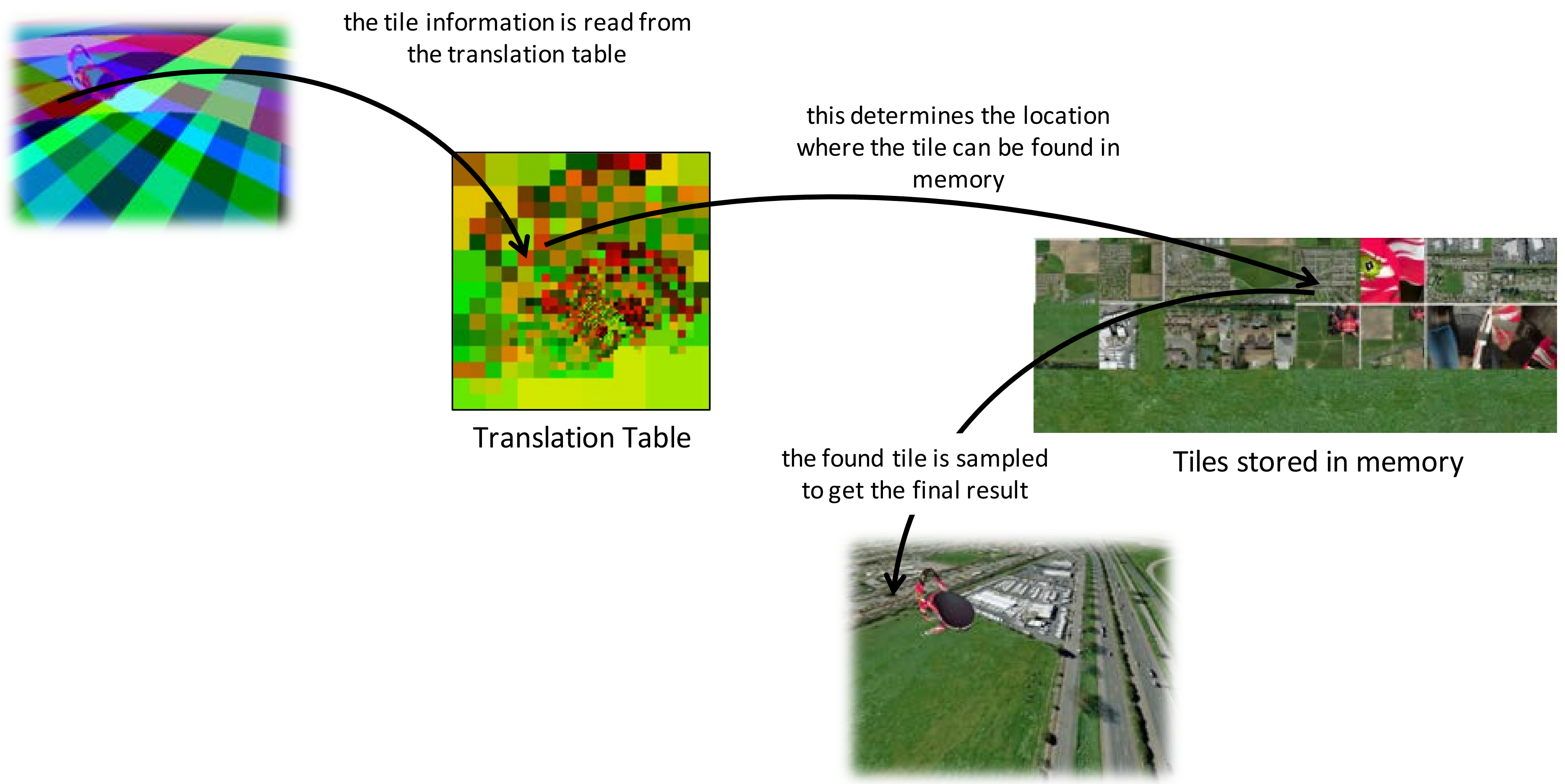
Multiresolution tile lay-out



Virtual texturing



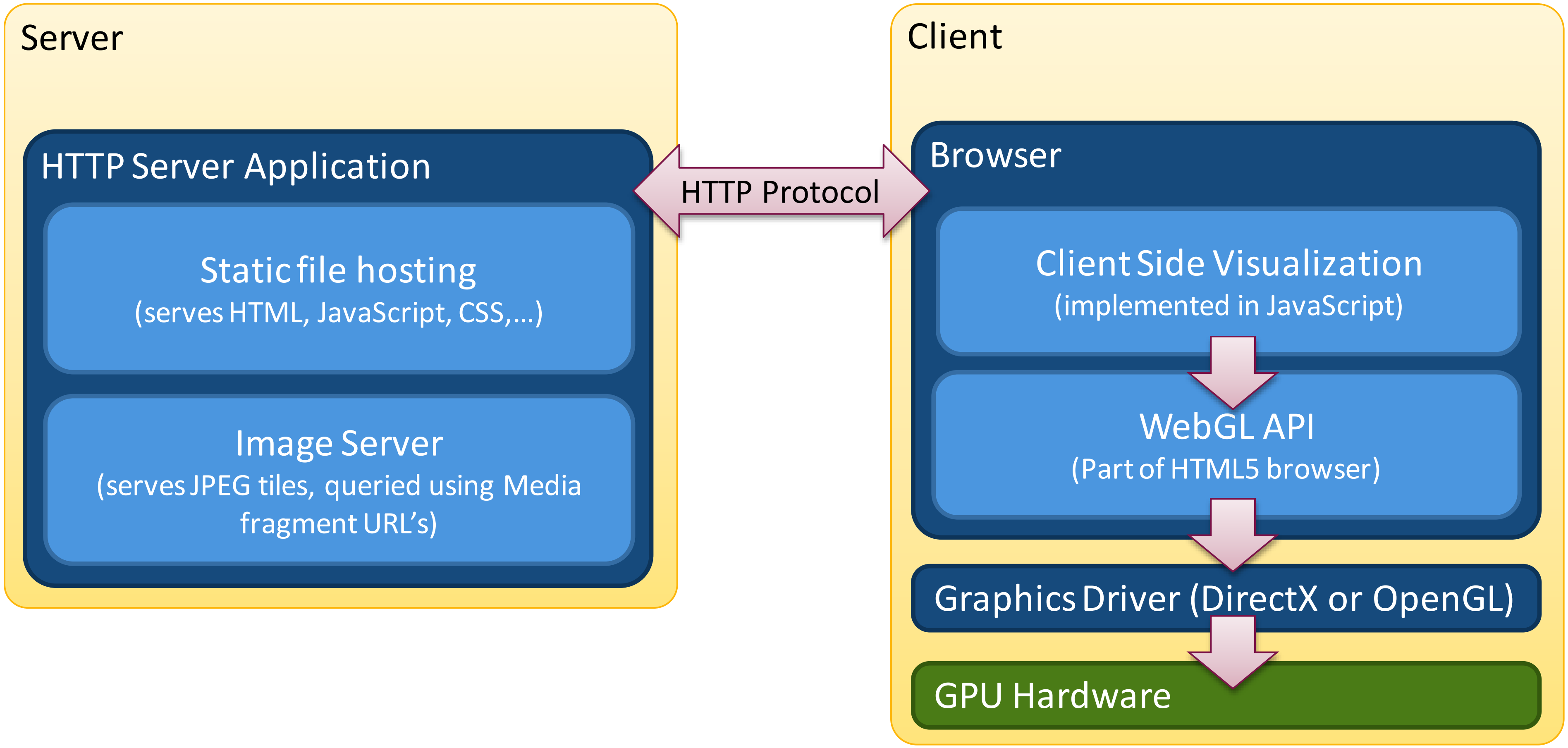
Rendering with a virtual texture


the tile information is read from the translation table
this determines the location where the tile can be found in memory
Translation Table
the found tile is sampled to get the final result
Tiles stored in memory

Overview

- Introduction
  - WebGL
  - Media Fragments
  - Virtual Texturing
- System Overview
  - Determining the working set
  - Page table generation
  - Page requests
  - Server Side
- Results
- Conclusions

Architecture Overview

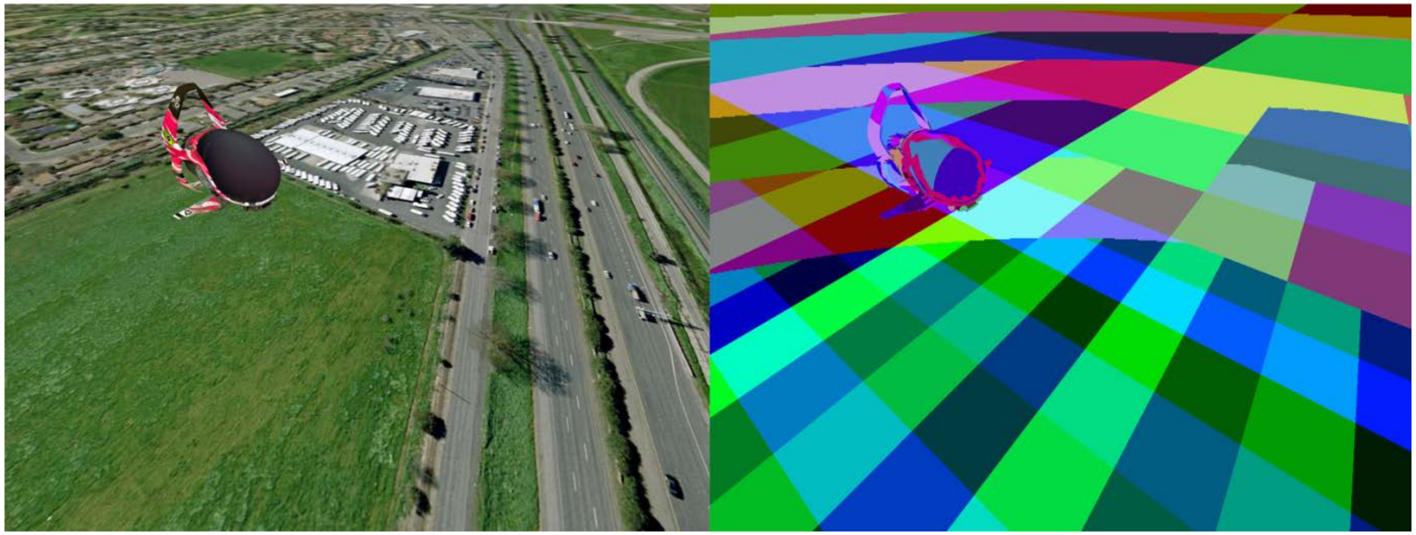

Server
HTTP Server Application
Static file hosting
(serves HTML, JavaScript, CSS,…)
Image Server
(serves JPEG tiles, queried using Media fragment URL's)
HTTP Protocol
Client
Browser
Client Side Visualization
(implemented in JavaScript)
WebGL API
(Part of HTML5 browser)
Graphics Driver (DirectX or OpenGL)
GPU Hardware

Determining the working set

- We have a tiled multi-resolution image but which tiles do we need to download
- Traditional 2D systems (e.g. Google maps, Deepzoom, …)
  - User set zoom level
  - Current scroll position
- This becomes a lot more complex in 3D
  - Geometry & texture coordinate dependent
  - Occlusion
  - Camera position & orientation
  - Camera field of view

Determining the working set in 3D

- Needs to determine what portions of the texture are needed for every pixel

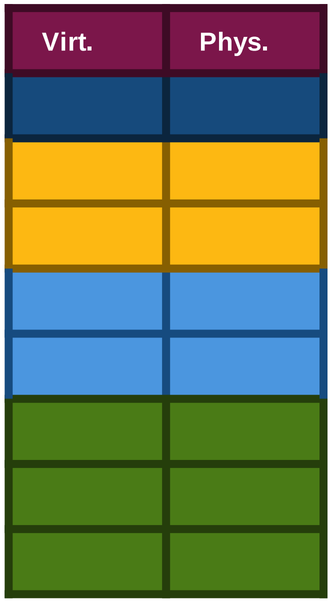


Page resolver optimizations

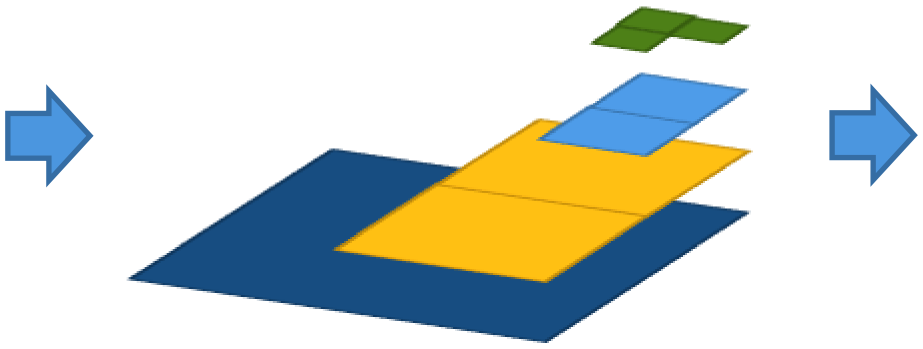
- Render the view to a low resolution off-screen buffer
- Low res does not contain information for every pixel
- However
  - Usually highly consistent between neighboring pixels
  - Cache works over multiple frames so it may get requested a few frames later anyway
- Read back this buffer to the CPU
  - Analyze this buffer using JavaScript code
  - Low resolution & type arrays make it fast

Accelerating the translation table

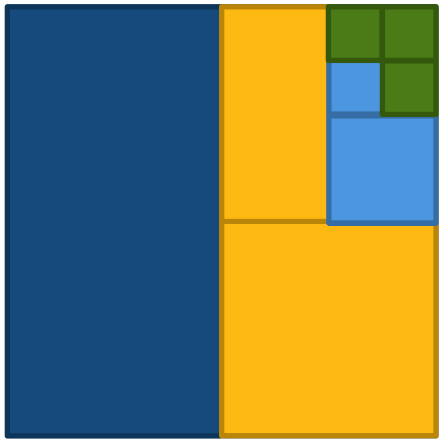
- The list of pages in the cache is converted to a vertex array
- The WebGL is used to rasterize quads into the translation table.



Miplevel-ordered list of pages



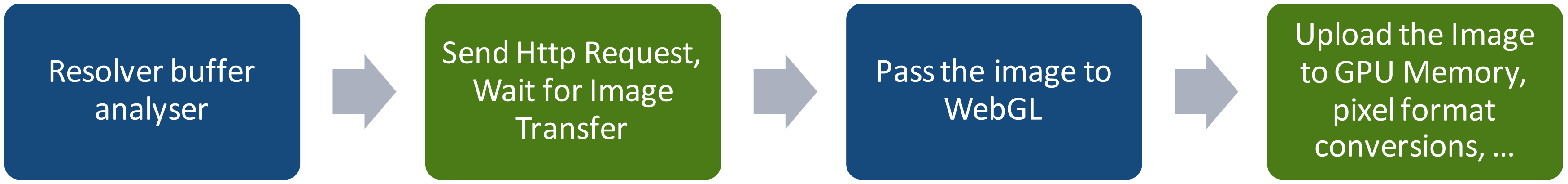
JavaScript code generates quads covering the page in virtual texture space



Results rendered to page translation table

Requesting Tiles

- We request quite a lot of tiles per second
- However we do not need to touch any pixel data using JavaScript
- JavaScript is just a conductor for things going on native code:


Resolver buffer analyser
Send Http Request, Wait for Image Transfer
Pass the image to WebGL
Upload the Image to GPU Memory, pixel format conversions, …

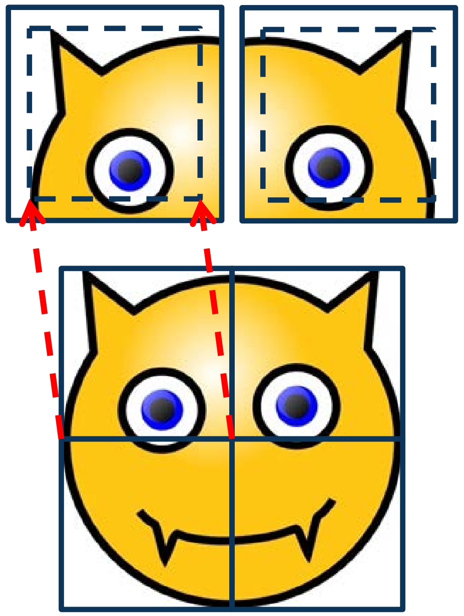
```
img = new Image()          img.onload          gl.texSubImage2D(img, …)
          …
  img.src = url
```

Server side

- On the world wide web
  - Custom Apache Module (C++)
  - Less overhead (only a single file handle per server thread)
- In-house
  - Lightweight HTTP frontend interfaces with backend system
  - Dynamically transcodes to JPEG tiles

Media Fragment URI's

- Use query URIs to retrieve the texture tiles
  - 2D rectangle queries for tiles within a resolution level
  - Track queries for the different resolution levels
  - `http://.../example.jpages?xywh=476,596,128,128&track=1`
- Advantages
  - Easy to switch between server implementations
  - Pixel based (vs. tile based) addressing hides implementation details



Overview

- Introduction
  - WebGL
  - Media Fragments
  - Virtual Texturing
- System Overview
  - Determining the working set
  - Page table generation
  - Page requests
  - Server Side
- Results
- Conclusions

Results

System	Chrome	Firefox	Opera
Render off-screen buffer	0.03	0.17	0.07
Read back buffer	10	2.9	6.5
Analyze buffer	1.4	2	1.2
Render main view	0.04	0.13	0.21
Total per frame	11.47	5.2	7.98
Single tile request	168	422	260
Single tile load	2	1.3	1.5
Total per tile	170	423.3	261.5

Results

- Chrome's out of process architecture suffers when reading back data to javascript.
- It is important to not only look at absolute numbers but also responsiveness
  - E.g. Firefox blocks the user interaction while requesting a page
- Mobile GPUs have to limited precision for our needs

Overview

- Introduction
  - WebGL
  - Media Fragments
  - Virtual Texturing
- System Overview
  - Determining the working set
  - Page table generation
  - Page requests
  - Server Side
- Results
- Conclusions

Conclusions

- WebGL allows us to do very data intensive tasks previously only available on high-end desktop apps
- However there are some hurdles to get it “production ready”
  - Browser performance: 422 ms to request a tile!?
  - CORS support for <img> resources
  - Asynchronous readback for WebGL (we have had this in desktop API’s for quite a while)

Demo

Visit the demo at:
http://schumann.elis.ugent.be/

Twitter:
@MMLab_Ugent @cholleme

Bonus Material

Server side scaling

- Many data-intensive sites use separate domains/servers
  - Different software optimized for dynamic/static data
  - Cookie-less domains to optimize http requests
- E.g. Google maps
  - Html & js hosted on maps.google.com
  - Images on a server cloud
    - mt0.google.com
    - mt1.google.com
    - khm0.google.com
    - …

Browser security: Same-Origin Policy

- Only allow http request to the same domain as the script came from
  - E.g. XMLHttpRequest (AJAX)
- Not enforced for pre-JavaScript resources
  - <script>
  - <img>
- Traditionally <img> was not a big issue
  - No way to access the content programmatically
  - Just an abstract DOM object

WebGL <img> restrictions

- WebGL can access image pixels
  - Directly via read-back
  - Indirectly via "performance" leaking
    - P.O.C implementations have been demonstrated
- Could leak the image contents to 3rd parties
- To avoid this, WebGL does not allow creating textures from images downloaded from a different domain

CORS

- CORS = Cross-Origin Resource Sharing
- An extension for the HTTP protocol that allows **servers** to indicate to the client that sharing the resource with other domains is OK
- The spec works with any resource
- However <img> is only supported in Firefox
- Other browsers support only XMLHttpRequest
  - Work in progress…