INTERACTIVE ZOOM AND PANNING FROM LIVE PANORAMIC VIDEO

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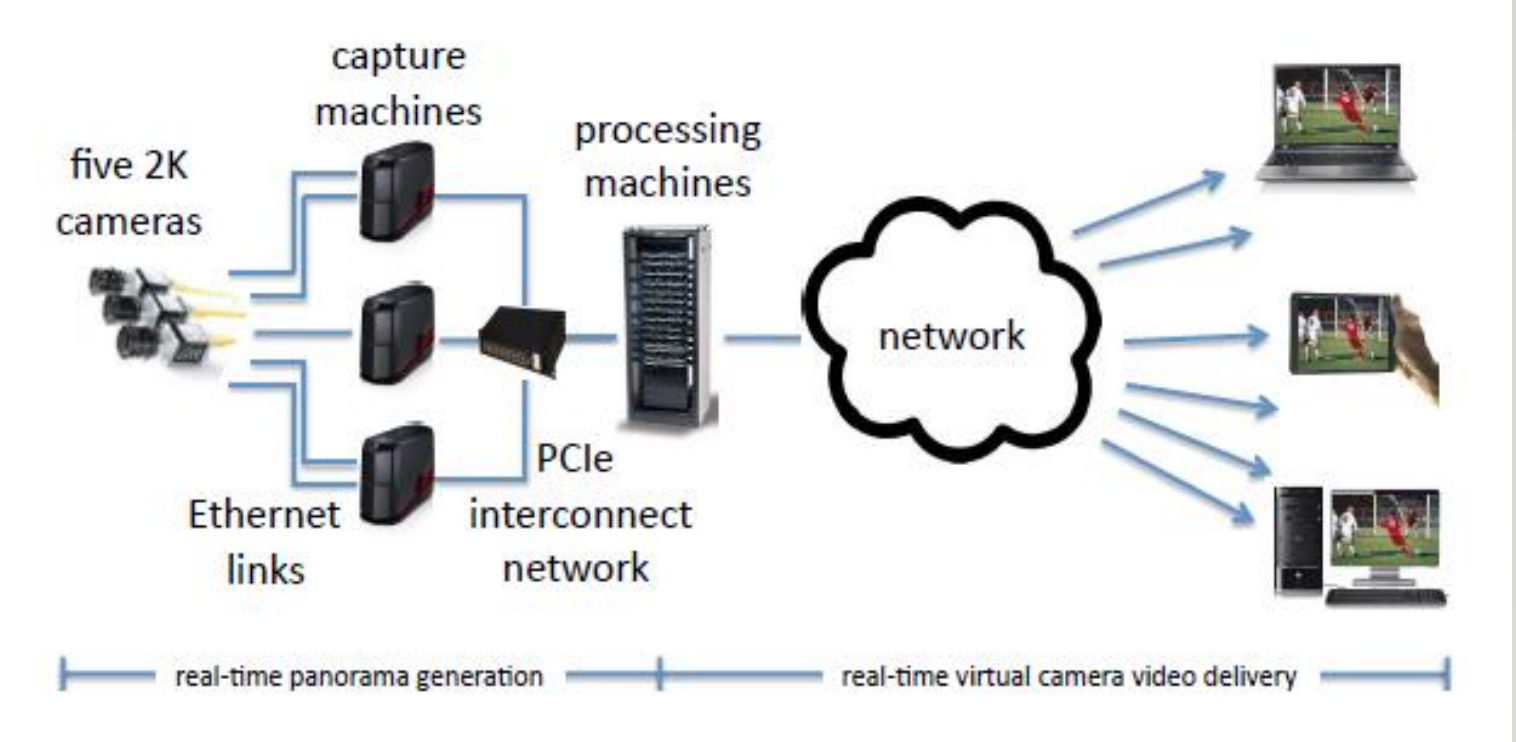
OVERVIEW

- The scenario is an end-to-end real-time streaming system that deploy in a soccer stadium in Alfheim, Norway
- The goal is to help thousands of concurrent users with their own operations such as zoom or panning the camera view
- The paper is focus on the design of panoramic texture projection and the building of virtual camera on the client side

SYSTEM INTRODUCTION



SERVER-SIDE VIDEO CAPTURE

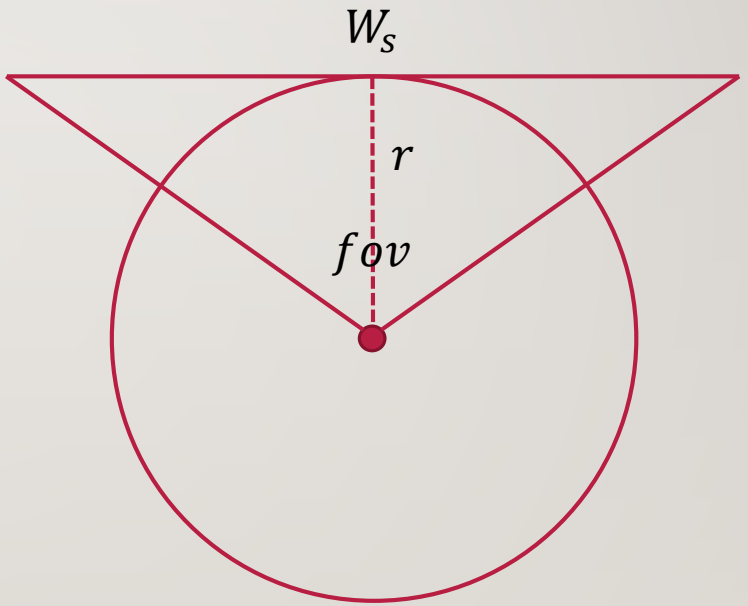
- Use 5 cameras with resolution of 2046*1086 pixels to do the filming
- Rotate and integrate them in a circular pattern, i.e., to look directly through a point in front of the lenses in order to reduce parallax effects
- Transfer the streams to panorama processing machine with point-to-point Ethernet network

SERVER-SIDE
CYLINDRICAL PROJECTION

- Retrieve a full set of synchronized frames from the camera streams with a frame synchronizer
- Generate the cylindrical panorama frames with a panorama stitcher
- Use a H.264 video encoder for the immediate frame delivery to the client side

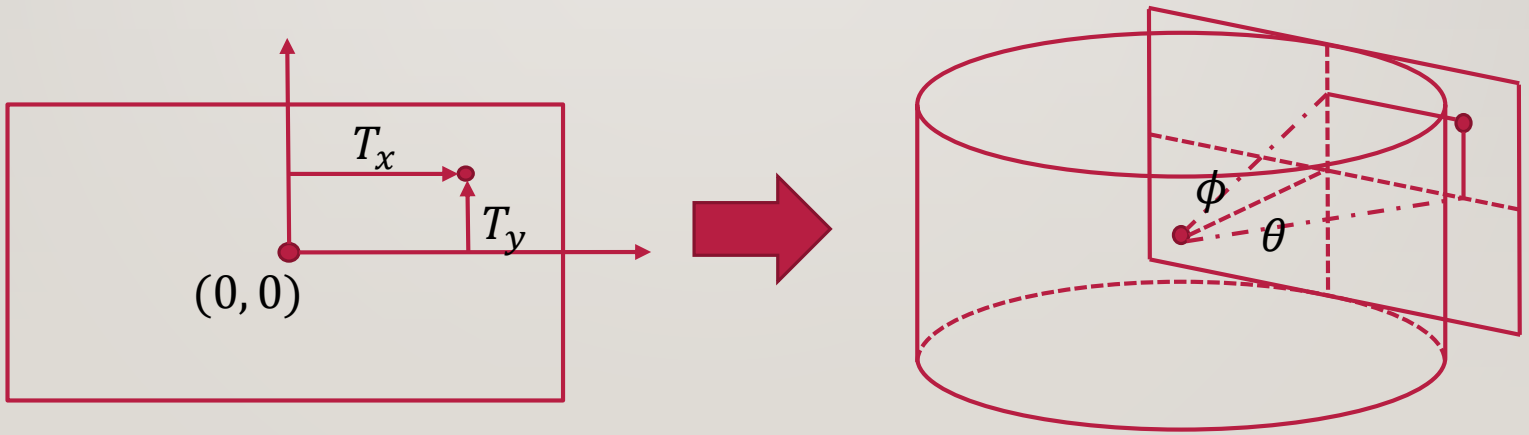
SERVER-SIDE CYLINDRICAL PROJECTION CONT.

- In panorama stitcher:
  - $r = \frac{W_s}{2 * \tan(\frac{fov}{2})}$
  - r : radius of cylinder.
  - W_s: width of source image.
  - fov: field of view.
- Center is where the cameras are



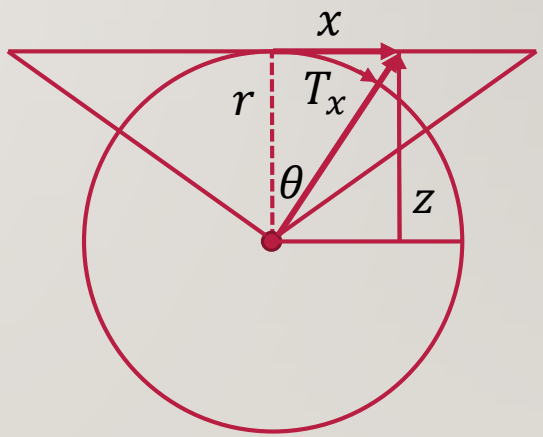
SERVER-SIDE CYLINDRICAL PROJECTION CONT.

- The unrolled cylinder forms a Cartesian coordinate system
- Each pixel (T_x, T_y) on the unrolled cylinder determines the corresponding horizontal (θ) and vertical (ϕ) angle of a ray from the camera center through this coordinate



SERVER-SIDE CYLINDRICAL PROJECTION CONT.

- And from the previous determination, we see that:
  - $\theta = \arctan\left(\frac{T_x}{r}\right)$ and $\phi = \arctan\left(\frac{T_y}{r}\right)$
- Then, for x, y, z, in 3D space where the ray intersects the image is:
  - $z = r$ and $x = \tan(\theta) * z$
  - $y = \tan(\phi) * \sqrt{z^2 + x^2}$
- And we can finally get the transform function:
  - $\theta = \arctan\left(\frac{z}{x}\right)$ and $\phi = \arctan(\frac{y*\sin(\theta)}{x})$

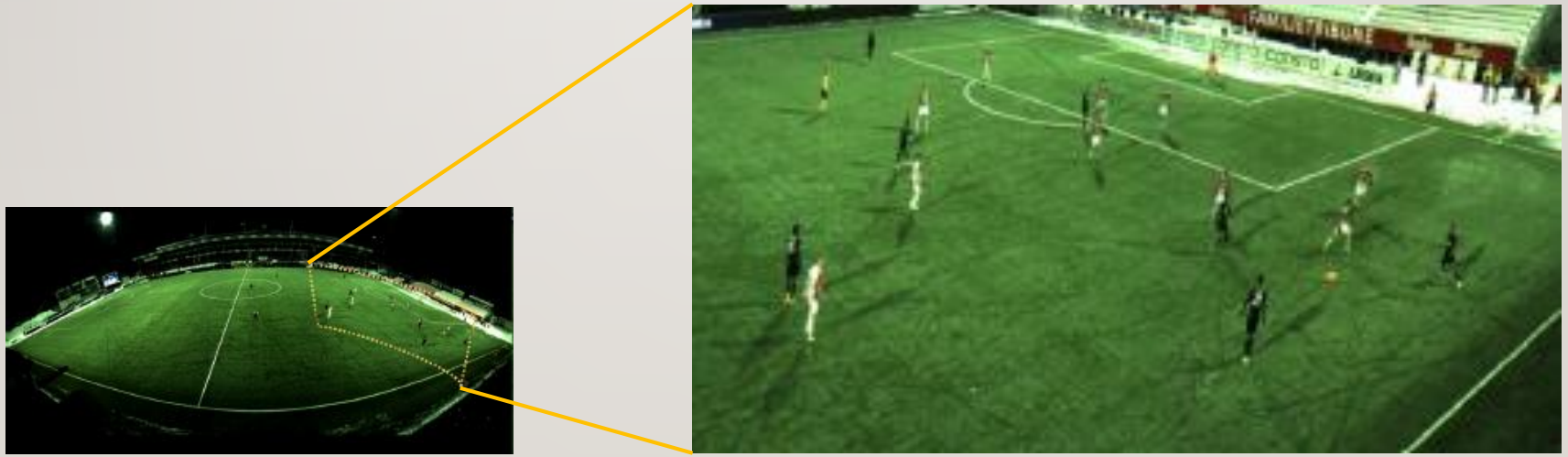


CLIENT-SIDE VIDEO HANDLING

- HTTP segment streaming is used for video downloading
- Served by Apache server along with a manifest file for informing client when the next file is ready
- Processing runs in the background without blocking the display thread and the user input thread

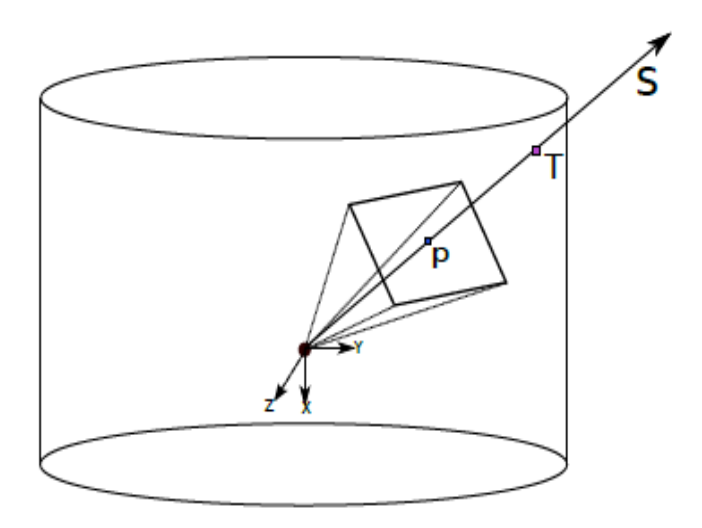
CLIENT-SIDE
CREATE VIRTUAL CAMERA

- Perform the video through a virtual perspective camera view, which is generated by the panoramic frame



CLIENT-SIDE CREATE VIRTUAL CAMERA CONT.

- First select a point P in panorama image, then the 3D point P project to image point q can be written by the following:
  - $\lambda_q = [K|0_3]\begin{bmatrix} R & 0 \\ 0_3 & 1 \end{bmatrix}\begin{bmatrix} 0_3^T & -C \\ 0 & 1 \end{bmatrix}P$
  - R: 3D distortion matrix (3x3)
  - K:The camera intrinsic matrix from focal length
- And the ray s from the cylinder center can be represented by:
  - $s = \lambda R^{-1}K^{-1}p$



CLIENT-SIDE
CREATE VIRTUAL CAMERA CONT.

- Then we can build the virtual camera view by finding each pixel's corresponding position on the cylindrical texture
  - $T_x = \left(\frac{W_p}{FOV}\right)\left\{arctan\left(\frac{-s(1)}{s(3)}\right)\right\} + \frac{W_p}{2}$
  - $T_y = \left(\frac{1}{2} - \frac{s(2)}{\sqrt{s(1)^2+s(3)^2}}\right) H_p$
  - W_p, H_p, FOV are the width, height and field of view of the panoramic texture respectively
  - (T_x, T_y) are the coordinates of the unrolled cylindrical texture
- There's gonna be some sub-pixel circumstances, so interpolation is needed

CLIENT-SIDE IMPLEMENTATION

- Lots of complex calculation involves in the algorithm
- Port the program to GPU:
  - Decoding video on the CPU
  - Calculation and fetching operation are performed on the GPU
- Nvidia CUDA supports direct OpenGL texture rendering
  - After fetching operations, the output written to the bound texture buffer on the GPU
  - Saving the transfer overhead from device to the host

CLIENT-SIDE COMPARISON

- Performed on a machine with an Intel i7-2600 CPU and an Nvidia GeForce GTX 460 GPU.

Approach	Average	Variance
Without GPU	255.7	35.8
With GPU	10.1	3.2

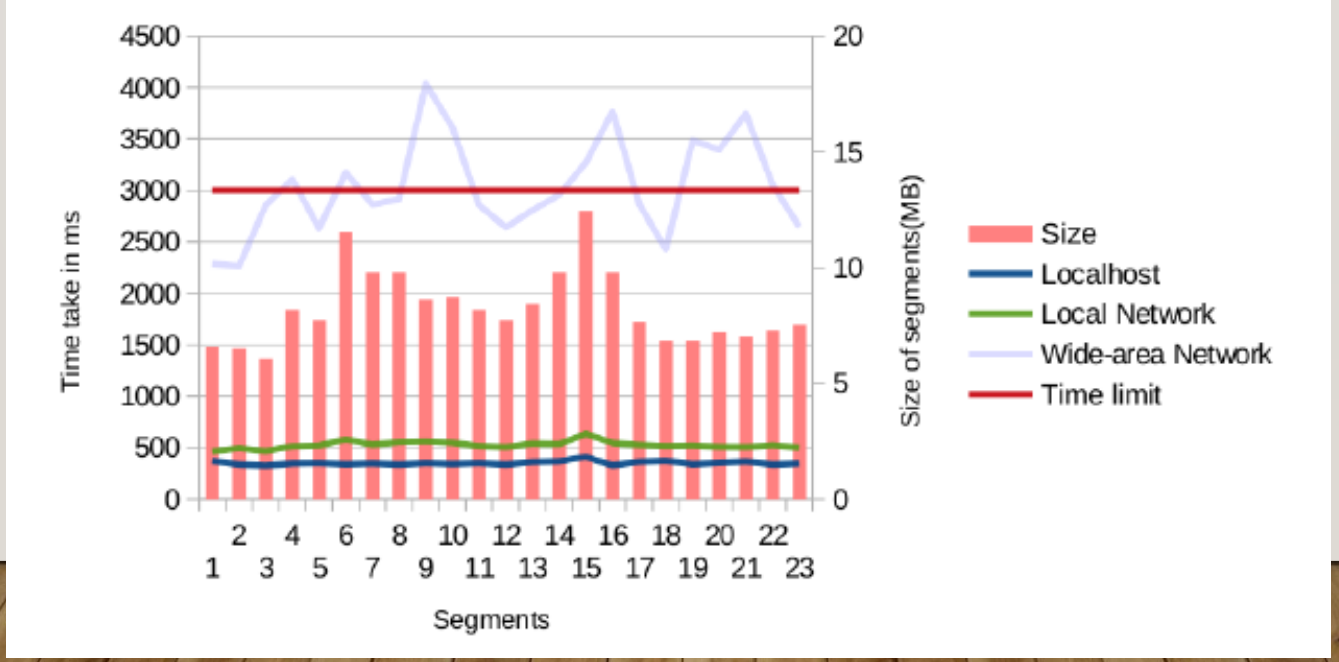
Table 1: Execution time per frame (ms).

CLIENT-SIDE
ZOOM AND PANNING OPERATION

- Panning: Modify the rotation angle of x-axis θ_x.
- Tilting: Modify the rotation angle of y-axis θ_y.
- Zoom: Modify the focal length f.

EXPERIMENT
VIDEO DOWNLOAD

- When separated with the real network, the client is still able to perform close to the 3-second smooth playout. The varies depend on the bandwidth available to client.



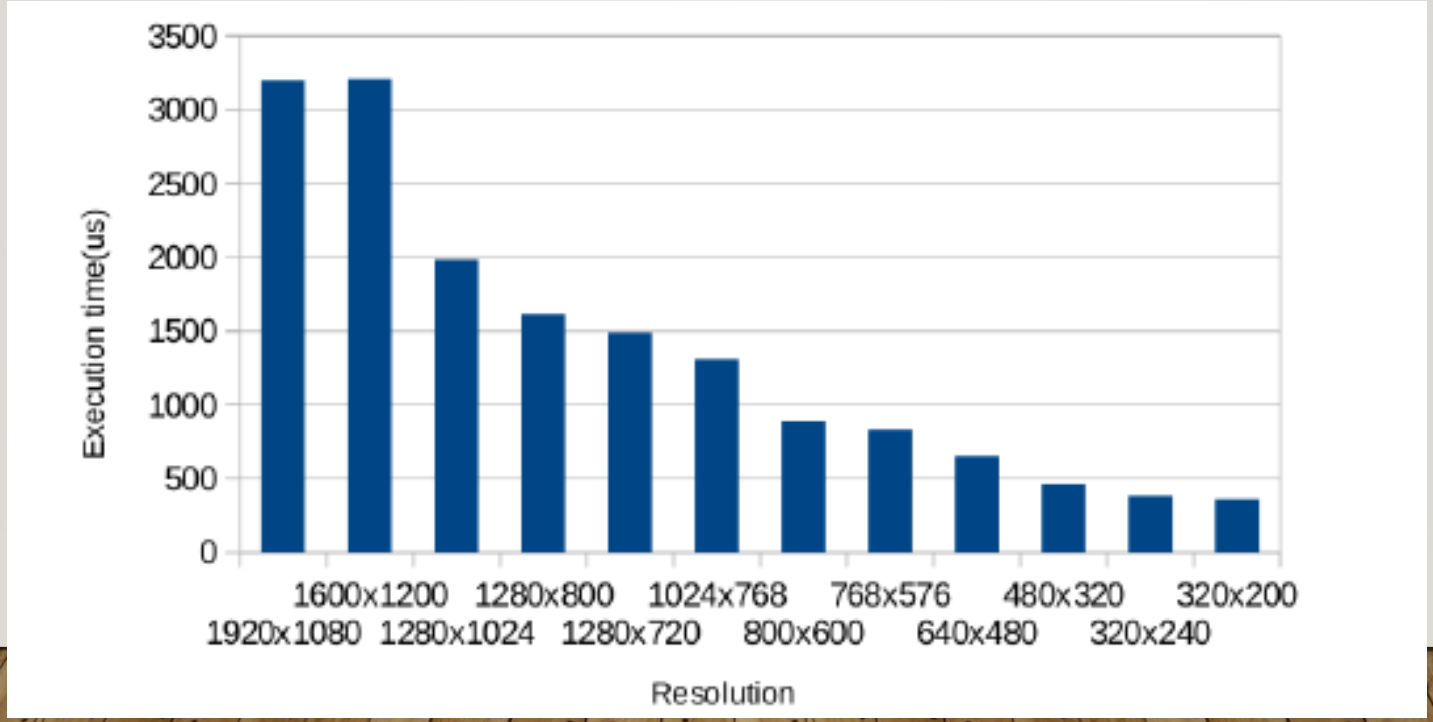
EXPERIMENT

INTERPOLATION

Nearest neighbor	bilinear	bicubic
2916 µs	2840 µs	3242 µs

EXPERIMENT
RESOLUTION

- The resolution has finite impact on performance, since the whole process has moved to GPU.



CONCLUSION

- Based on video stream of some cameras, processed and stitched into a panorama video, we are able to support any free-view angle from the camera array, i.e., a virtual camera.
- The frame of the virtual camera can be generated in less than 10 ms on a computer with a standard GPU. It can then easily be scaled to support many concurrent users.

THX FOR LISTENING