GPU TECHNOLOGY CONFERENCE

Visualizing a Car's Camera System

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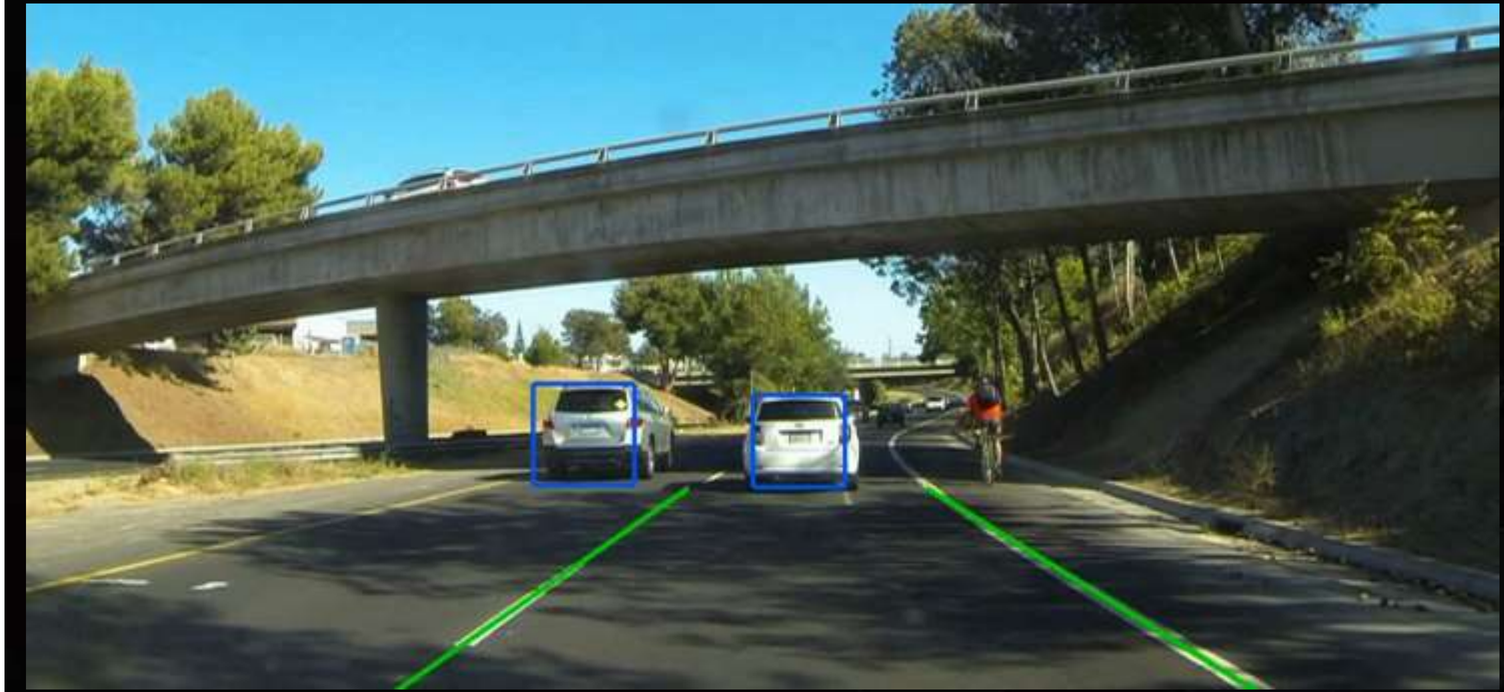
Previously,NVIDIA GPUs:
All things graphics
in the car



Goal:
Driver Assistance

and, ultimately:
autonomous driving!

INTRODUCING NVIDIA DRIVE™ PX

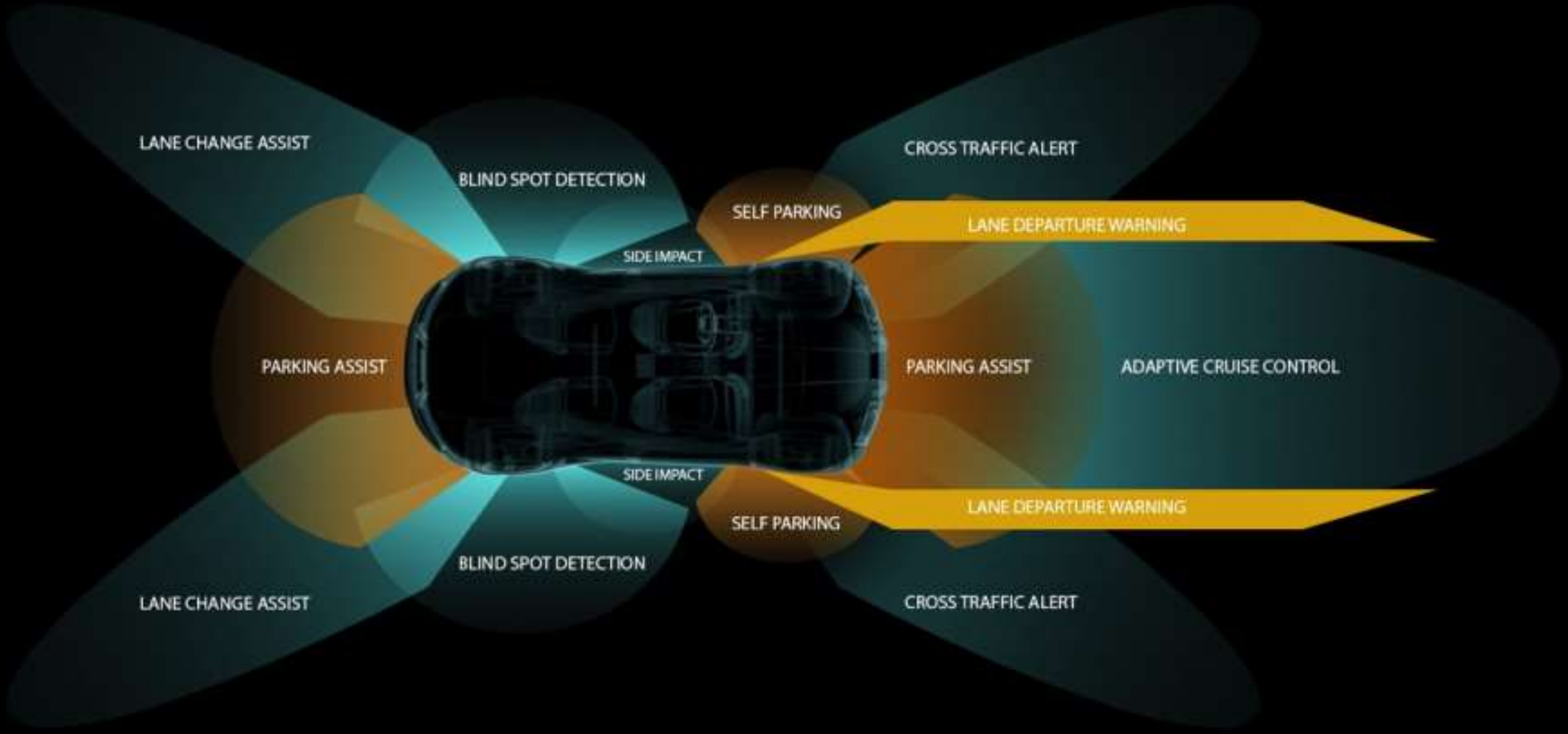
AUTO-PILOT CAR COMPUTER

Dual Tegra X1 ● 12 camera inputs ● 1.3 GPix/sec

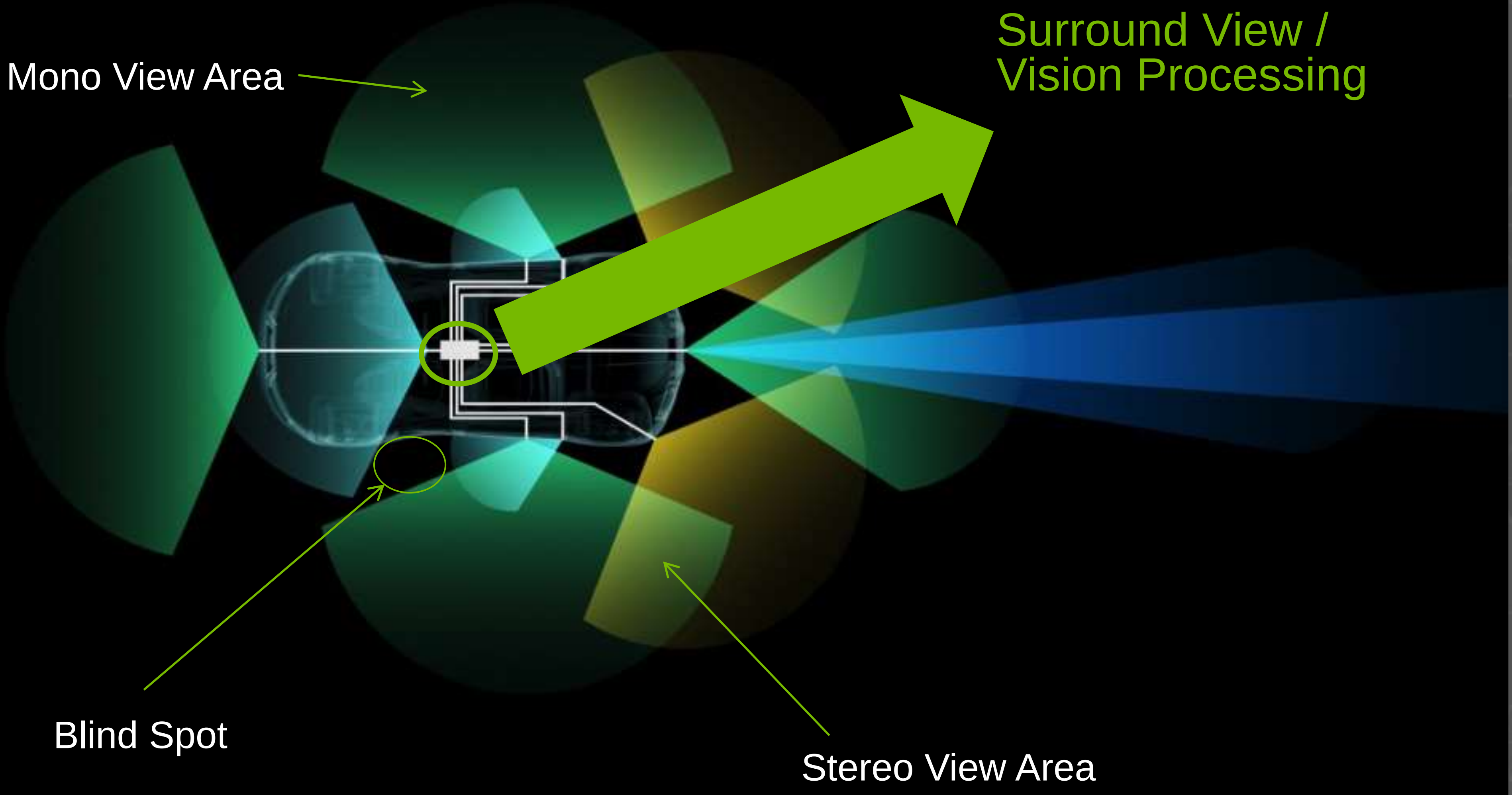
- 2.3 Teraflops mobile supercomputer
- Surround Vision
- Deep Neural Network Computer Vision

NVIDIA DRIVE™ PX
SURROUND VISION

Sensor system tasks



“View Space”


Mono View Area
Surround View /
Vision Processing
Blind Spot
Stereo View Area

Topview Reconstruction

We have camera images (and camera positions) -
How does one obtain a top view image?

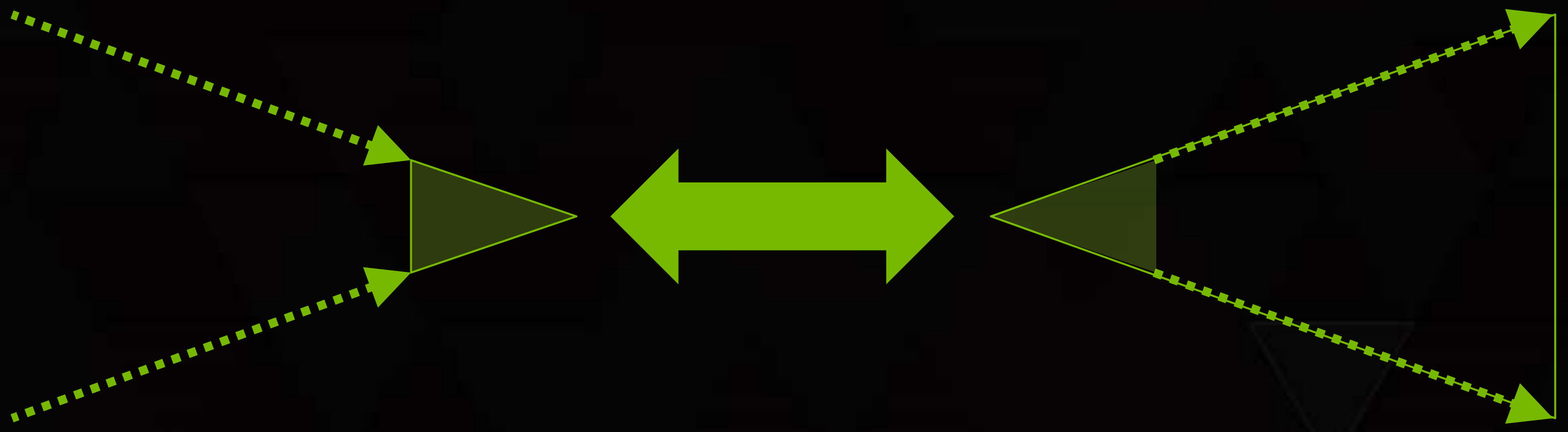
Camera images

Reconstructed top view

?

Camera/Projector dualism

A camera image is a recording of light – simulate light projection from camera position!

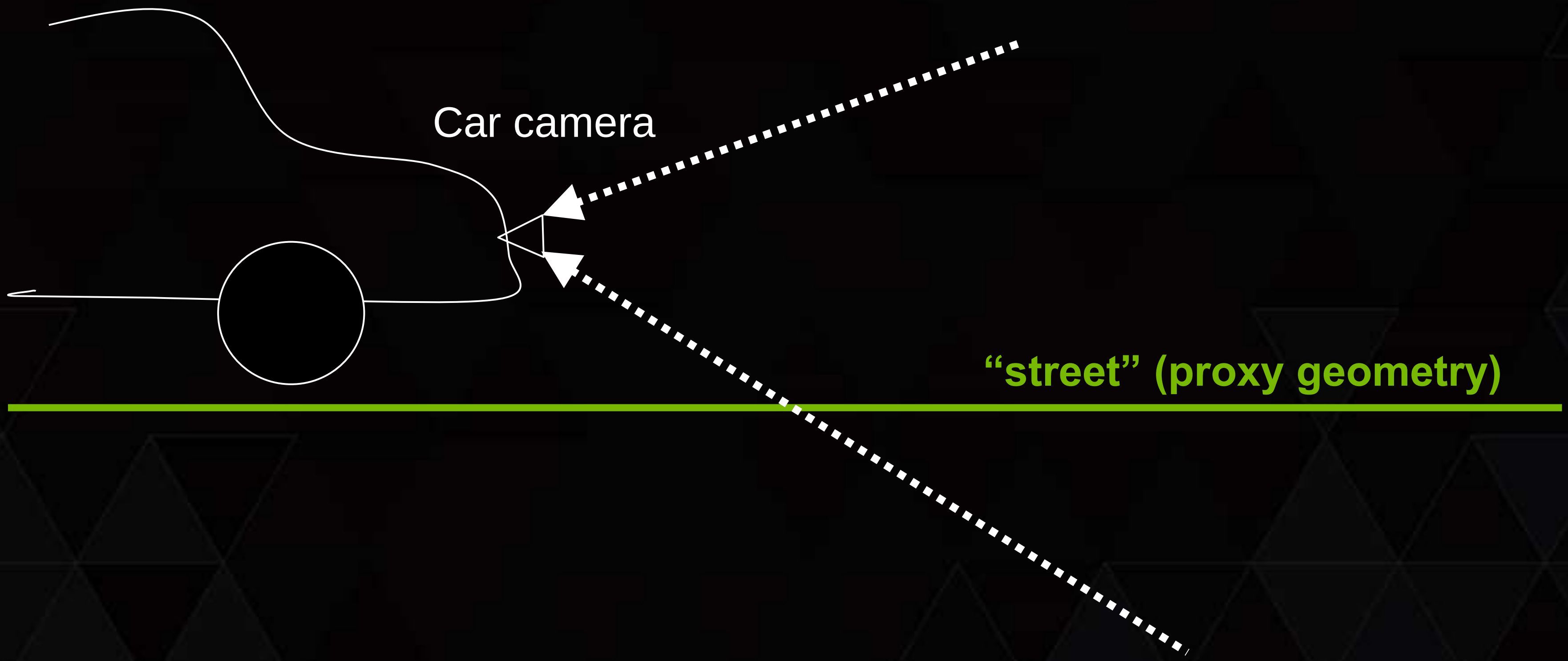


Camera images
“record”
incoming light
in real world

Project “recorded” light
into virtual world!

Geometry Proxy

Place “projection canvas” in virtual world (proxy geometry) at position where recorded object was relative to camera.

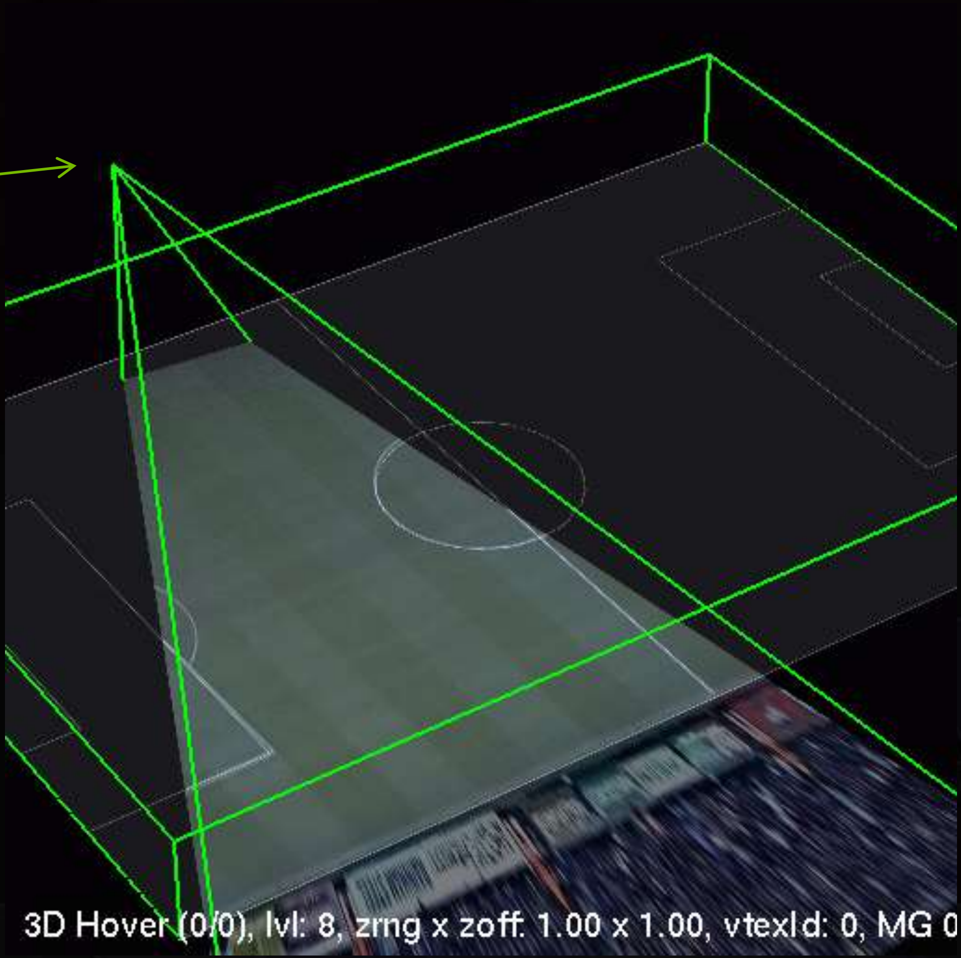


Example : Soccer Field

In: Camera images from soccer field, camera positions known from calibration.

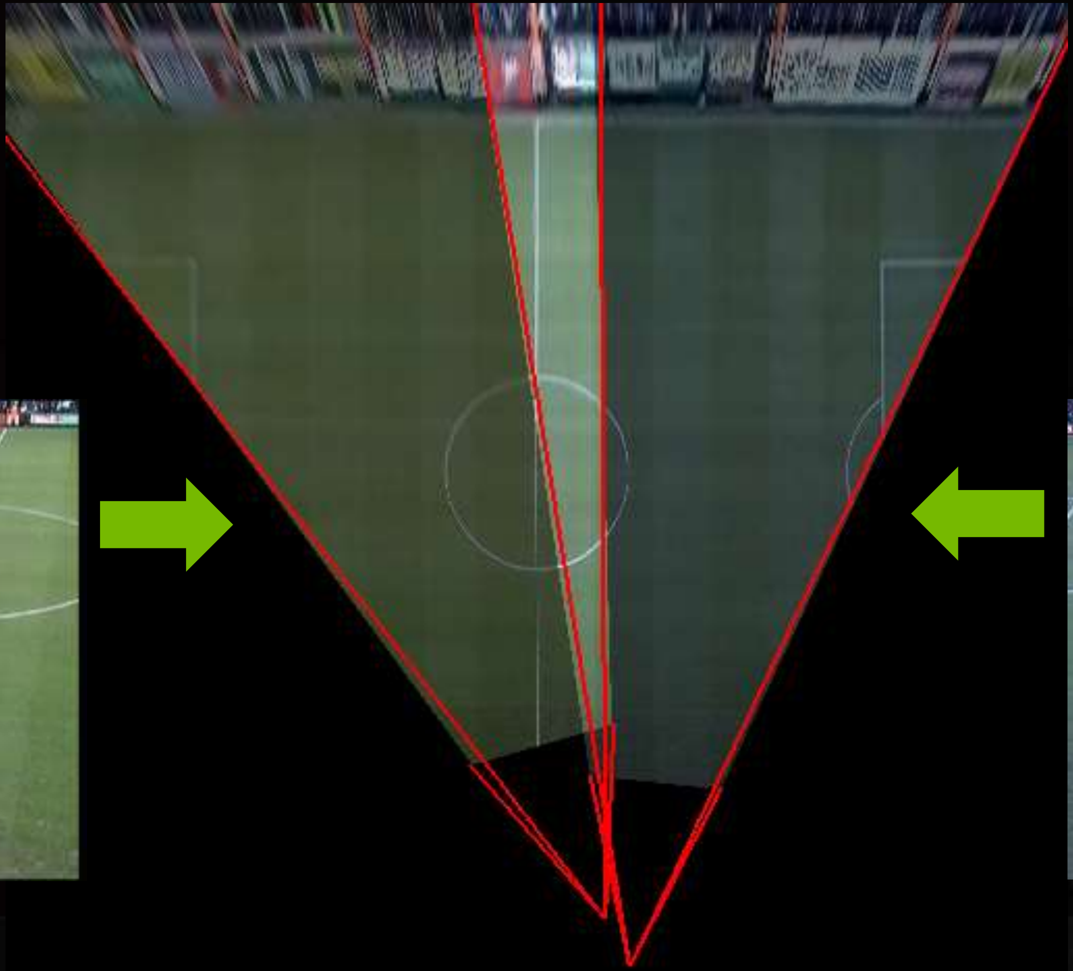
Camera image

Proxy geometry



Camera/Projector Overlay

Now render geometry with a blend of multiple camera images. Voila! TopView. ☺



[Video Topview, 5:49]

Car View Calibration and beyond

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Approach and goals

Traditionally, camera calibration is achieved using image homographies achieved by camera vs. camera calibration.

However, the GPU can easily visualize taken camera images in a 3D world, and complement with objects.

This leads to a merger of car camera visualization and car view reconstruction – already in the design process.

Camera calibration by proxy

We have a way to reconstruct a top view. But what happens if the camera positions are not well calibrated?

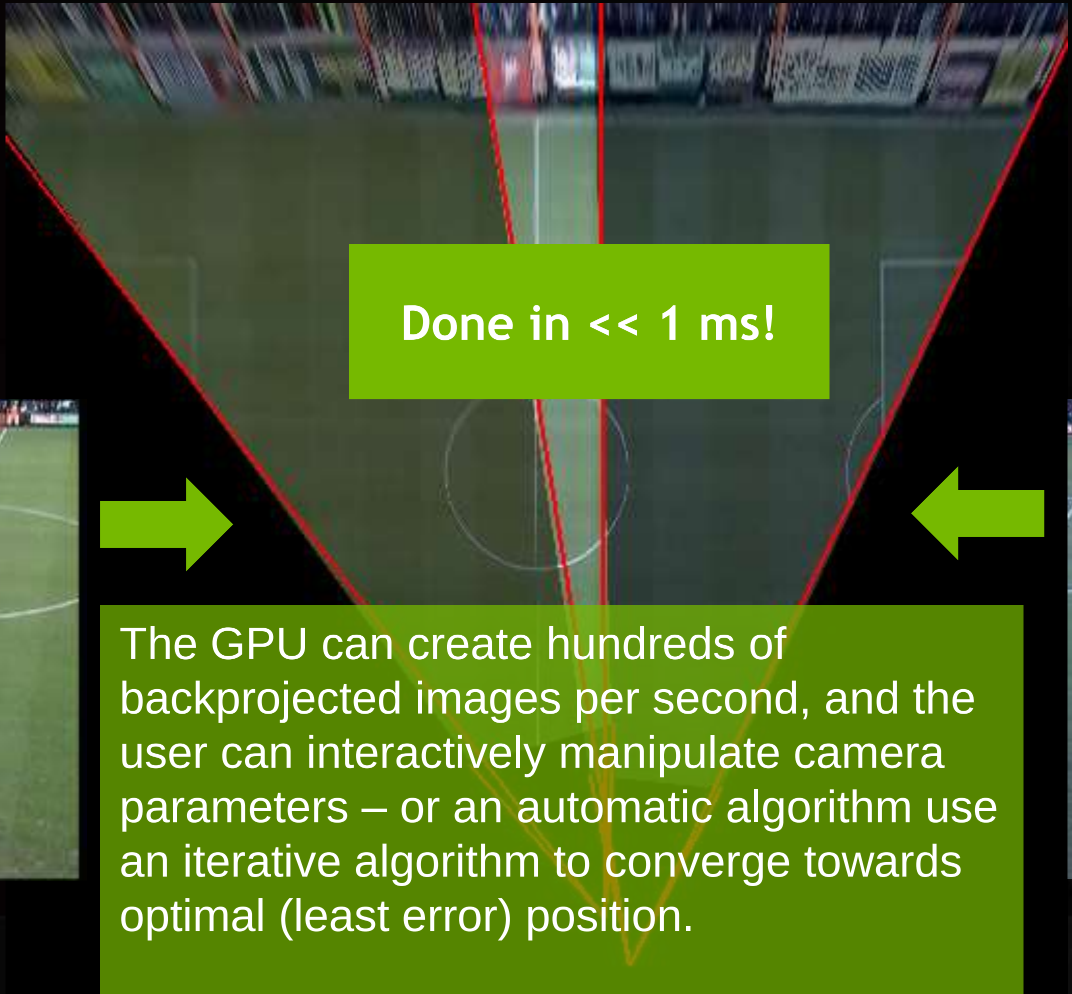
-> We can use a known proxy for camera alignment!

Isn’t that expensive?

No.

Camera/Projector Overlay

Now render geometry with a blend of multiple camera images. Voila! TopView. ☺

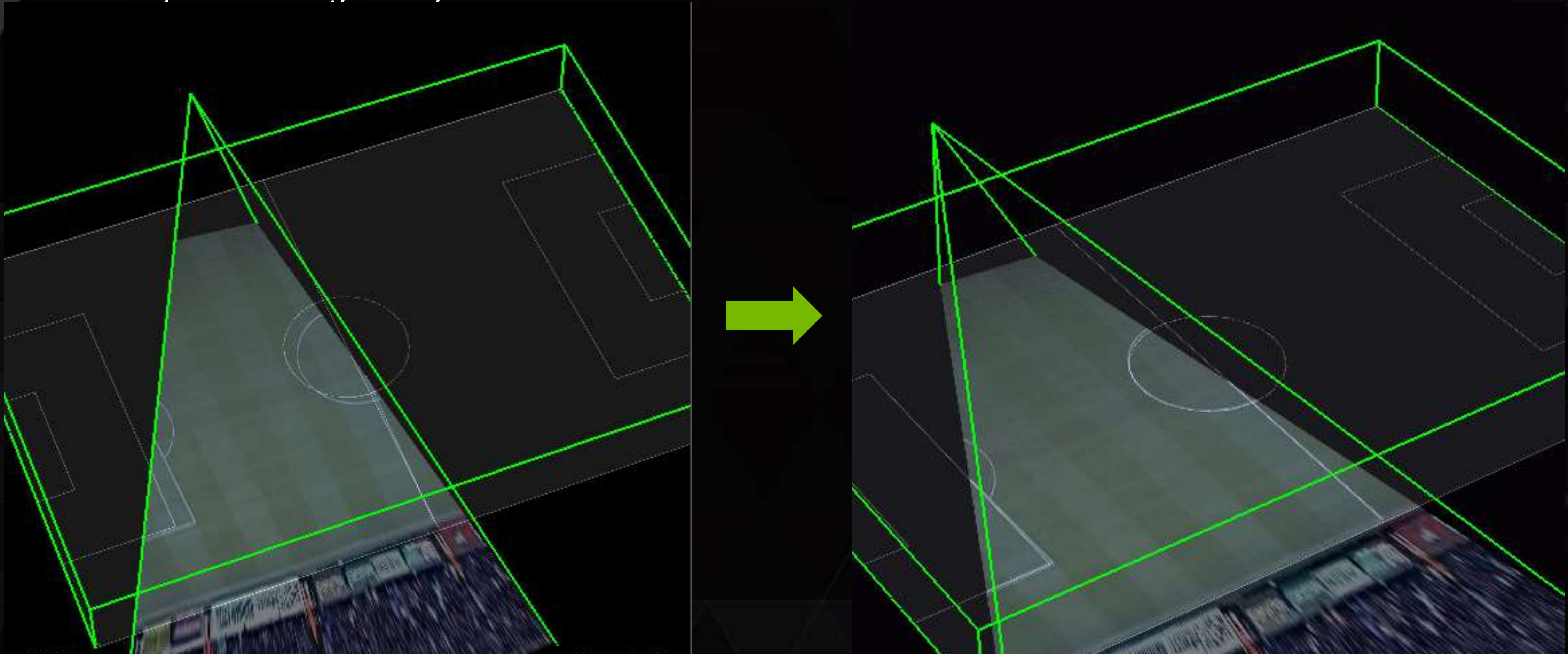


Done in << 1 ms!

The GPU can create hundreds of backprojected images per second, and the user can interactively manipulate camera parameters – or an automatic algorithm use an iterative algorithm to converge towards optimal (least error) position.

Manual Camera Calibration

Camera images given, but _not_ the exact camera positions. Soccer field geometry was known.
With real-time projections onto the soccer field and changing the camera positions,
they can be aligned by a human within minutes.



Camera calibration by proxy

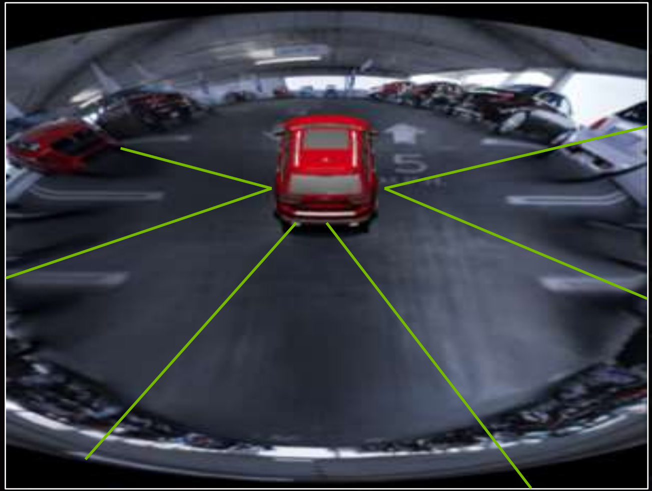
Why ? Example: During checkup, drive the car into a calibration room.

http://www.luxuryconcretefloors.com/projects/garage/checkered_floor%20pap%2012%20car%20garage.jpg

Camera calibration by proxy

It is now easy to see where the cameras are misaligned, and even possible to re-adjust the camera positioning <u>interactively</u>.

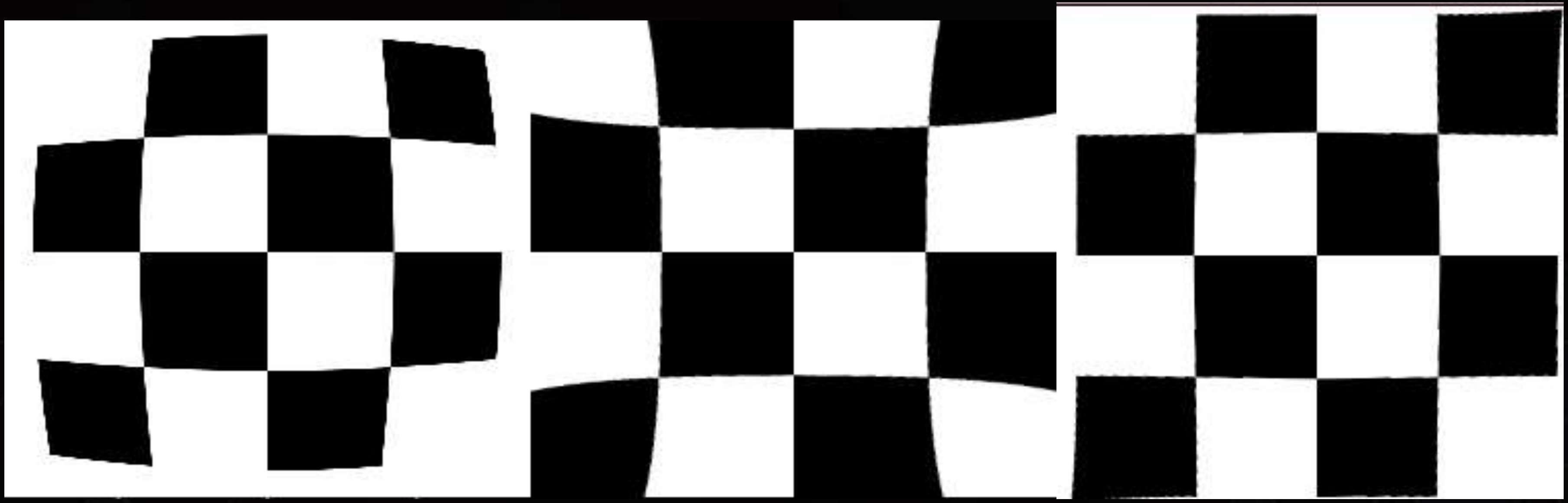
https://ec.europa.eu/jrc/sites/default/files/7200_hi-res.jpg



Human insight into the car's vision system!

Intrinsic Camera Calibration

Given a proper proxy, even lens parameters and camera FOV can be calibrated interactively.



Camera output | Overcompensated | Best result with k^2

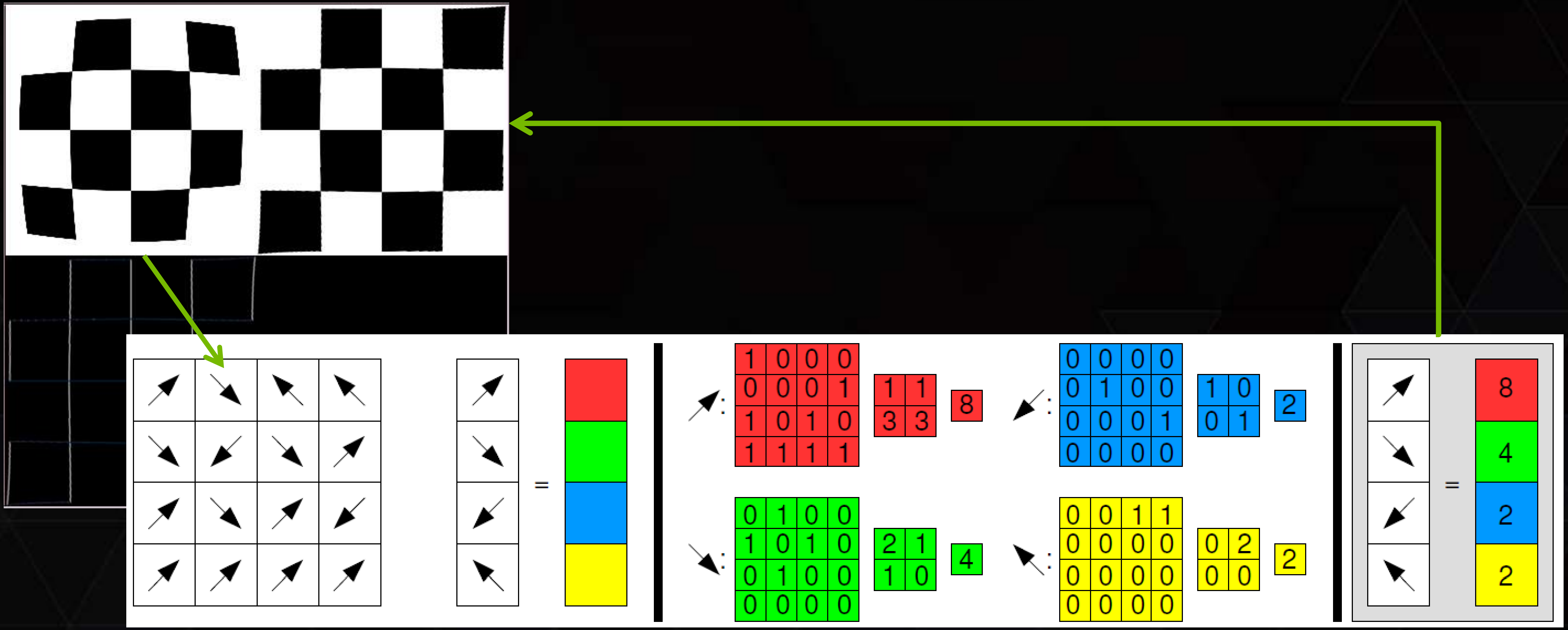
Further development

Approach is user-controlled and manual.
But nothing keeps it from being automatized

Can step by step introduce “assistants”,
and verify their performance against
hand-optimized calibration result.

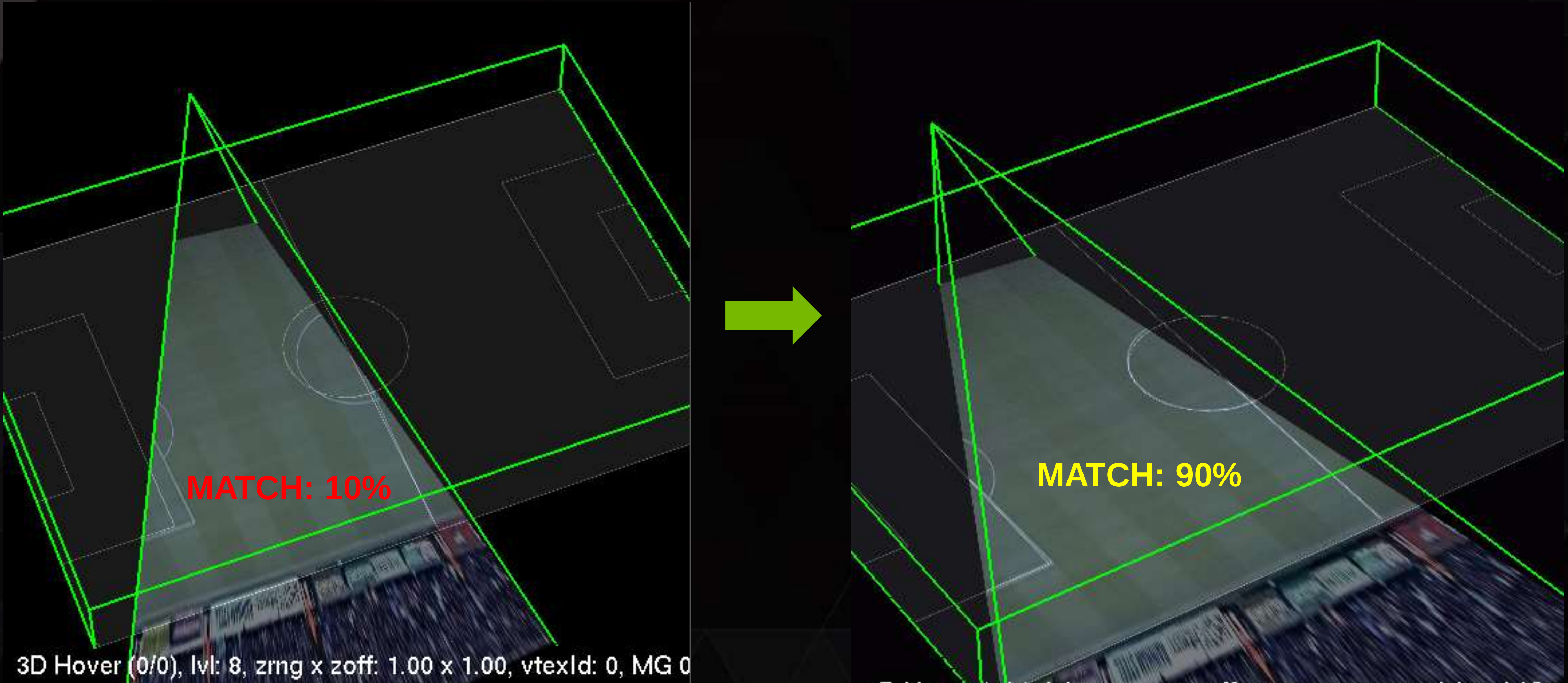
Intrinsic CamParam Assistant

Variance from edge direction histograms guide assistant towards best compensation.



Extrinsic CamParam Assistant

Uses pixel agreement (SAD) between geometry proxy model and camera view (or inbetween several blended camera views) to guide parameter choice.



Depth Reconstruction Usage

Depth reconstruction

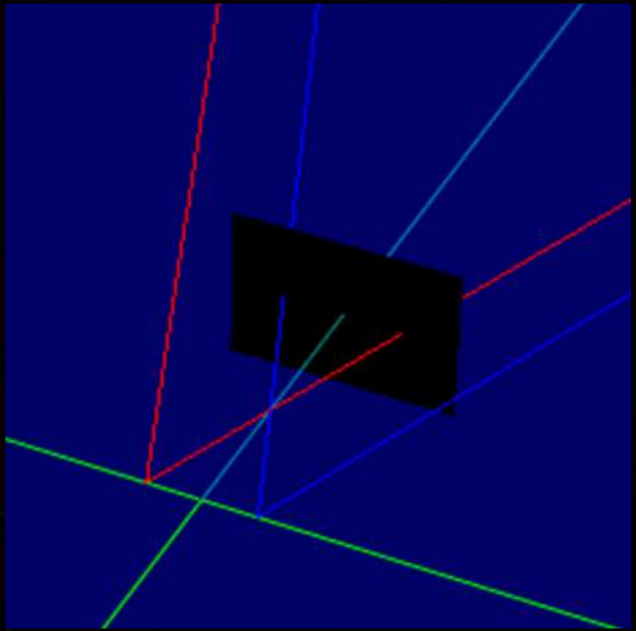
Now that camera positions are known, reconstruction of perceived world can commence.

We place out surfaces in the virtual world, and see if the incoming projections match/co-incide -> indicator that surfaces are at right position.

Again, manual at first (depth surface editor), then automatized (“magic wand for right depth”).

Depth reconstruction from projection

Iterate through depth planes, check camera view agreement for righ depth hypothesis:



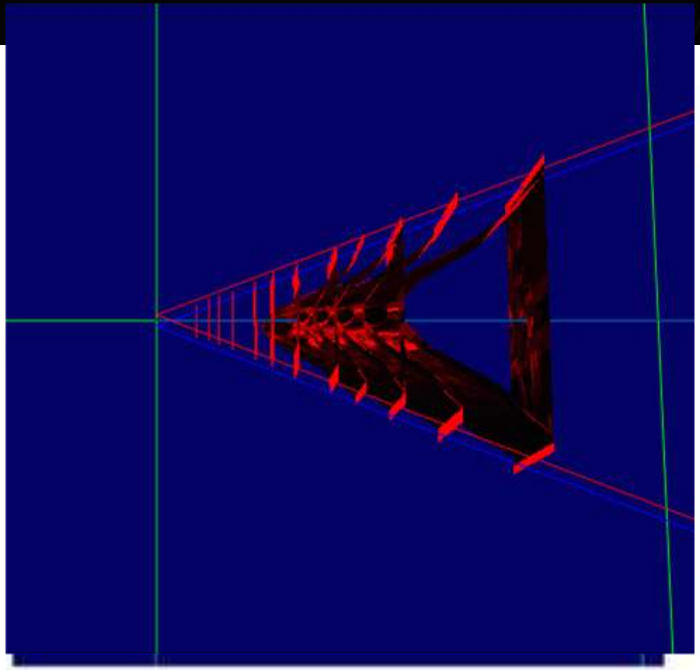


Figure 5.4: Evolution of a depth hypothesis, shown as red surface. Blue and red lines: left and right camera view extents.

More at http://www.geofront.eu/thesis.pdf

Depth reconstruction from projection

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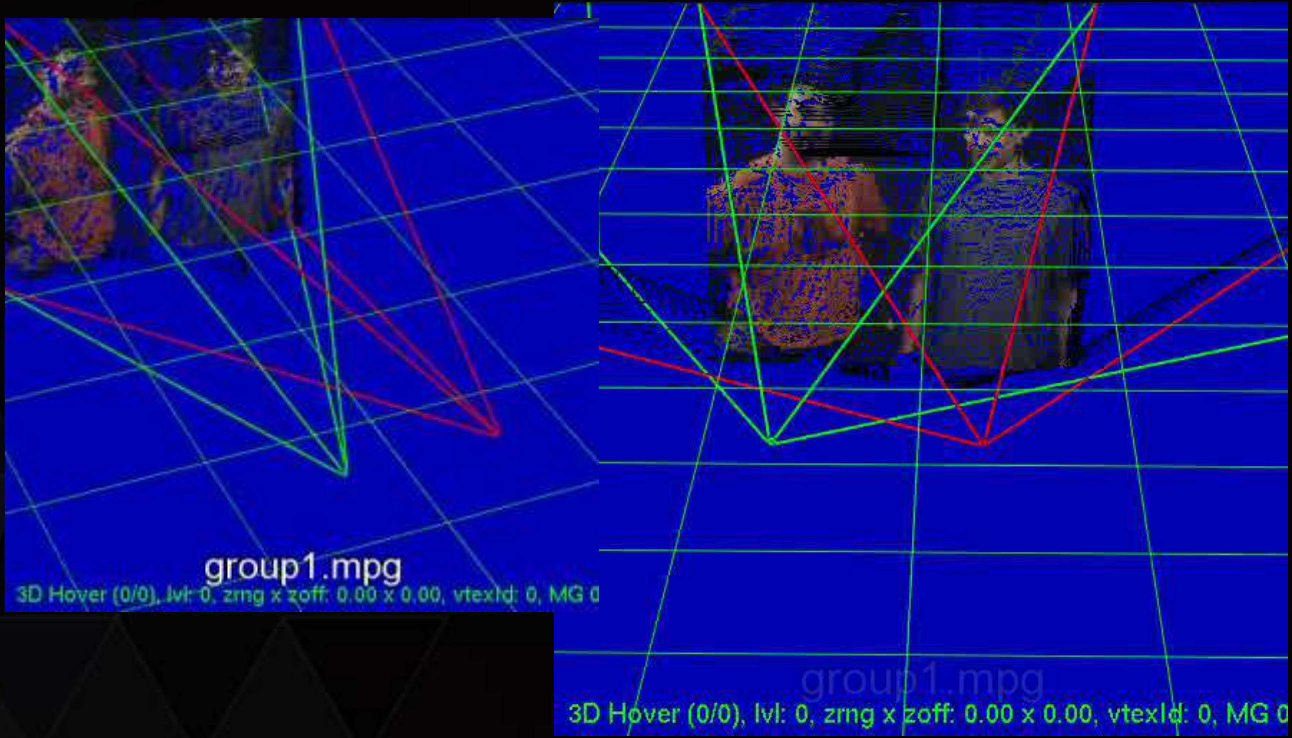

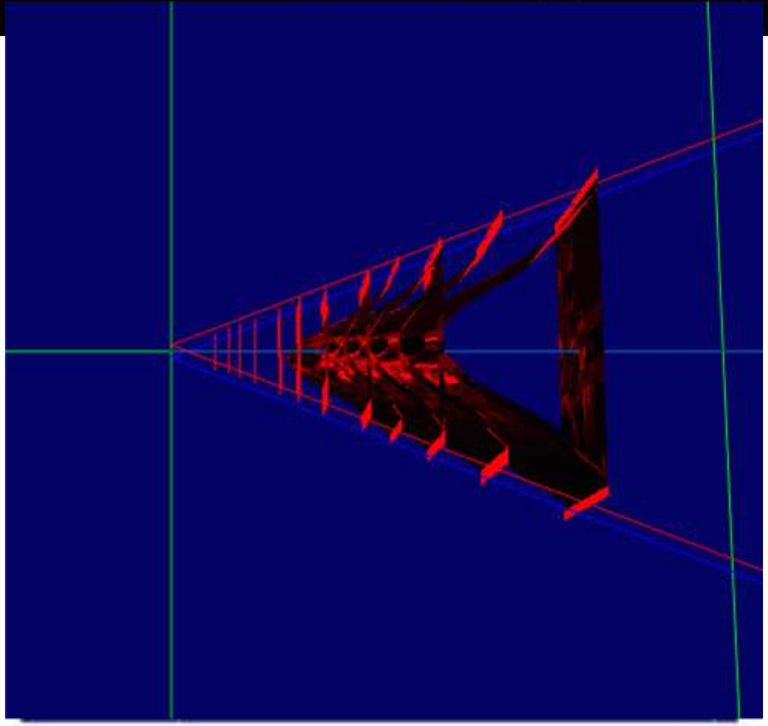

Figure 5.4: Evolution of a depth hypothesis, shown as red surface. Blue and red lines: left and right camera view extents.

Advantage: Visualizes all depth hypothesis in world coordinates, can render geometry proxy to verify algorithm.

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Conclusion

The GPU can assist in detection and remedy of camera decalibration, using real-time *projected camera data*.

By designing and calibrating in a virtual world scene, much of the forthcoming car visualization is implemented.

The GPU framework uses OpenGL concepts, and can be used on both developer systems (desktop PCs) and in the car’s embedded system (code re-usage).

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Gernot Ziegler <gziegler@nvidia.com> says

THANK YOU

For your kind attention.

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#GTC15

(More camera vs. projector ideas at
http://www.geofront.eu/thesis.pdf)

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