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
Sensor system tasks
“View Space”

- Mono View Area
- Blind Spot
- Stereo View Area
- Surround View / Vision Processing
Topview Reconstruction

We have camera images (and camera positions) - how does one obtain a top view image?
Camera images "record" incoming light in real world

Project "recorded" light into virtual world!

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

Now render geometry with a blend of multiple camera images. Voila! TopView. 😊
[Video Topview, 5:49]
Car View Calibration and beyond
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.
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. 😊

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.

Done in << 1 ms!
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%202012%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 interactively.

Human insight into the car’s vision system!

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

MATCH: 10%

MATCH: 90%
Depth Reconstruction Usage
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 right depth hypothesis:

Depth reconstruction from projection

Iterate through depth planes, check camera view agreement for right depth hypothesis.

Advantage: Visualizes all depth hypothesis in world coordinates, can render geometry proxy to verify algorithm.
The GPU can assist in detection and remedy of camera de-calibration, 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).
THANK YOU

For your kind attention.

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