3D Reconstructed Models For Driving Simulation & Testing

NCI Research Day 20/06/22

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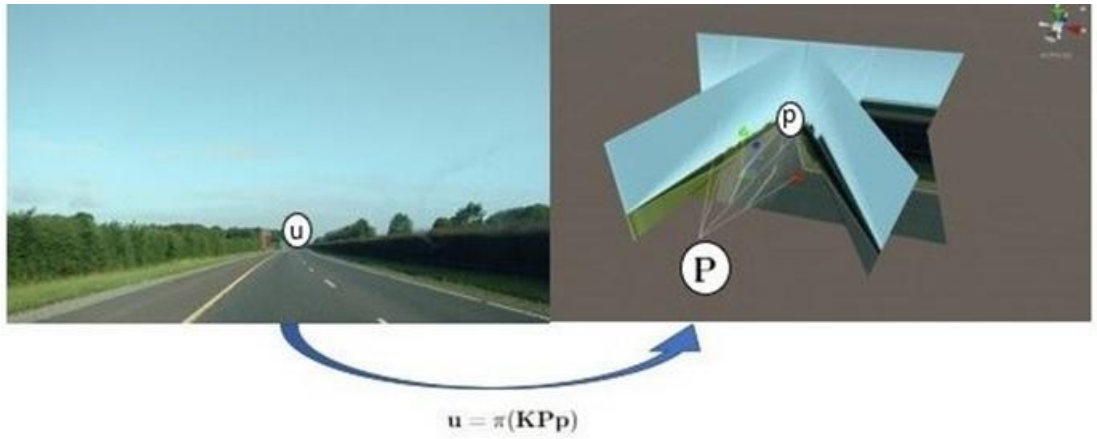
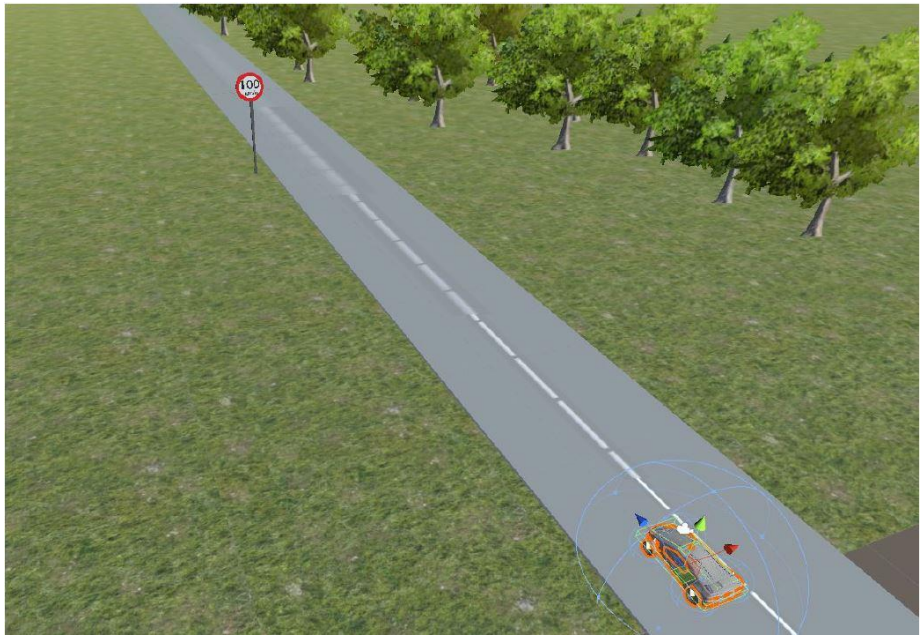
Overview

- Background
- Ideas
- What we did?
- How it looks
- Conclusions
- Questions

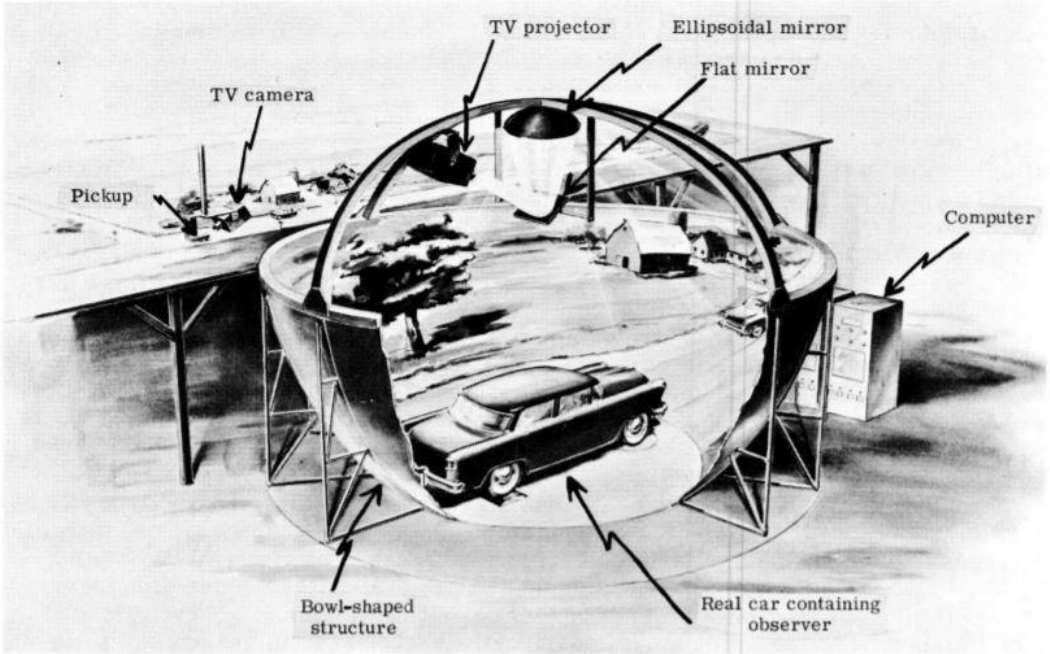


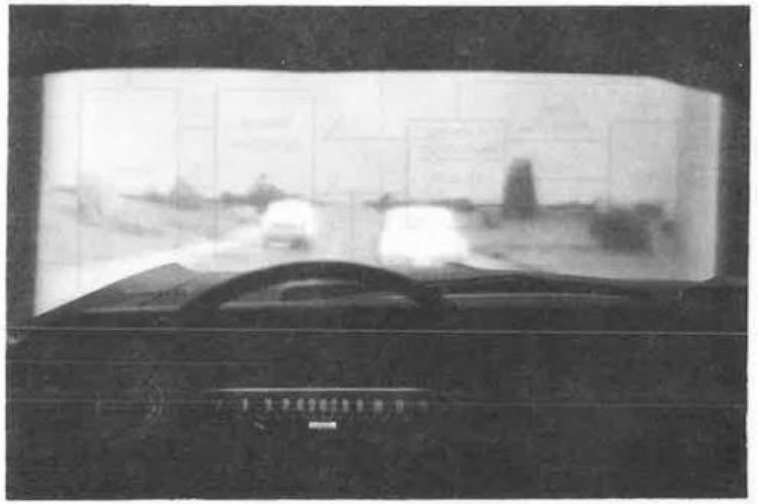


Background –Driving Simulation

Video Based Driving Simulation:

- 1958 Hutchinson describes a driving simulator that uses video footage of previously driven roads
- 1971 Weir develops a driving simulator connected to a scale model on a conveyor belt.





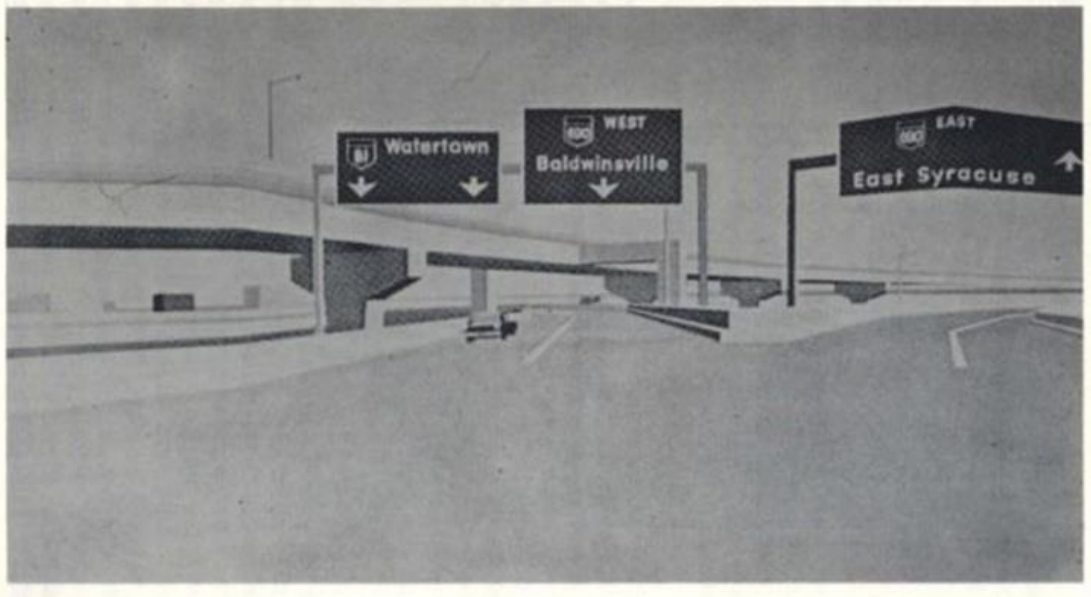
Background –Driving Simulation

Driving simulation then began to transition to a more computer based build rather than using cameras.

Starting with analogue based setups.

Then graduating to digital simulators in the 1970's.

The reliance on digital displays would grow as it enabled fast creation of environments and it was easy to control.



Background –Driving Simulation

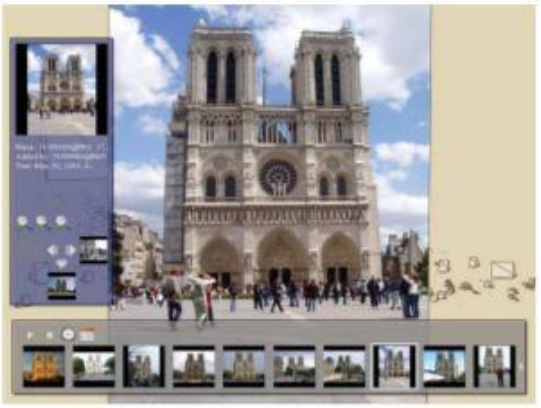
3D models of driving simulators got more detailed and eventually included light reflection and a good feel of depth.

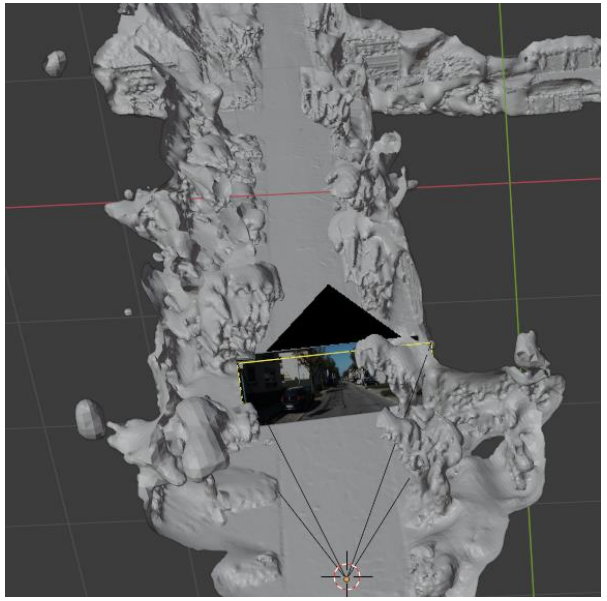
As graphics got better the attention in research shifted to tactile responses using large capsuled environments.

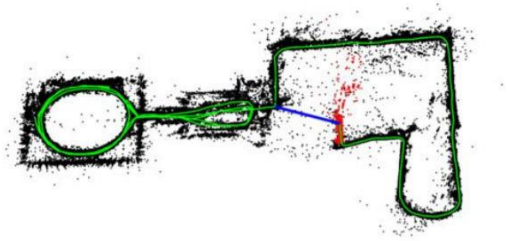
Background -3D reconstruction

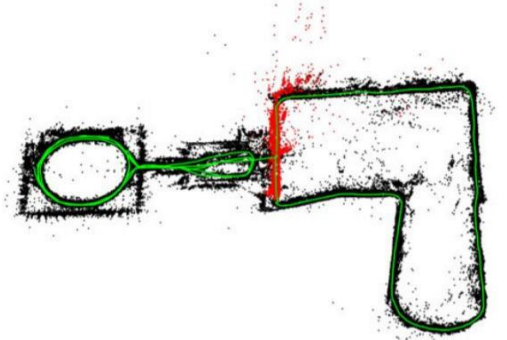
Over the last 20 years there has been a lot of development in scene representation and understanding of visual perception.

Using many images of the same scene we can reconstruct 3D models of that scene. This is called structure-from-motion.







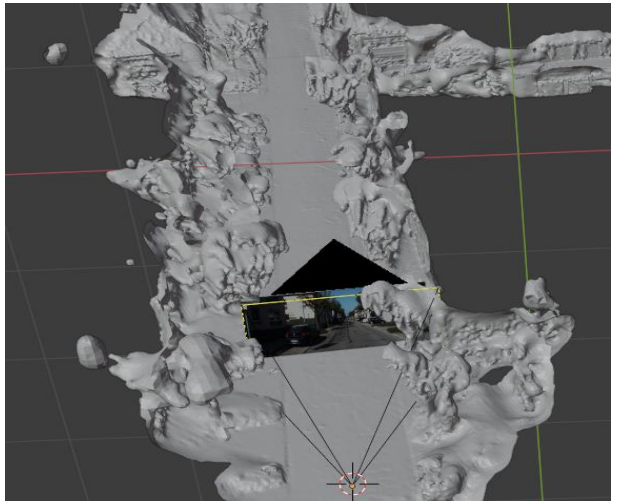


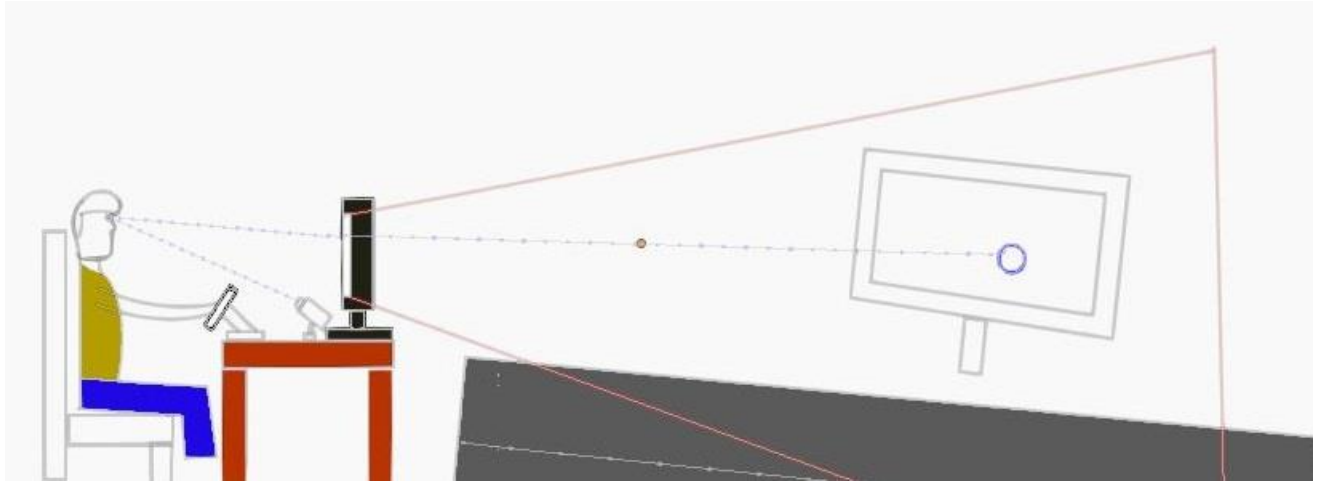
Our Idea

Reconstruct a 3D model from image features using a structure from motion algorithm.

Use a process known as projective texture mapping to make the models look photo-realistic.

Allow a user to drive within this environment for experimentation.





3D Reconstruction

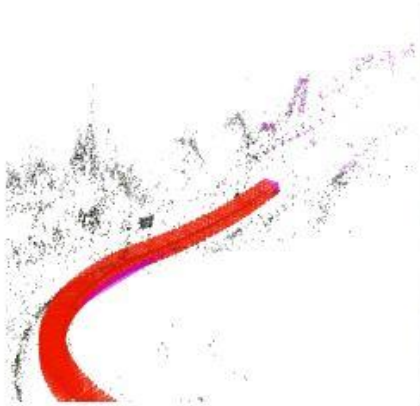
COLMAP structure from motion library was used.

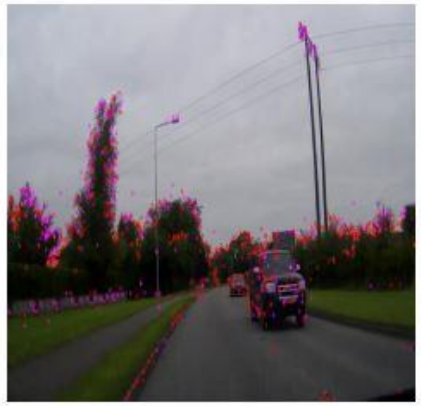
Inputs:

- camera intrinsics, K
- A set of RGB image operating over the image space domain $\Omega \subset \mathbb{N}^2$. Image space coordinates translated to a colour image C where each pixel $c : \Omega \rightarrow \mathbb{N}^3$.

Outputs:

- 3D dense mesh model $\mathcal{M}$ with points $p \in \mathbb{R}^3$.
- Set of depth maps $\mathcal{D}$ with each pixel $d : \Omega \rightarrow \mathbb{R}$.
- Set of poses $\mathcal{P}$. Each pose, P, consists of a rotation R and translation t and can be composed into a single matrix:





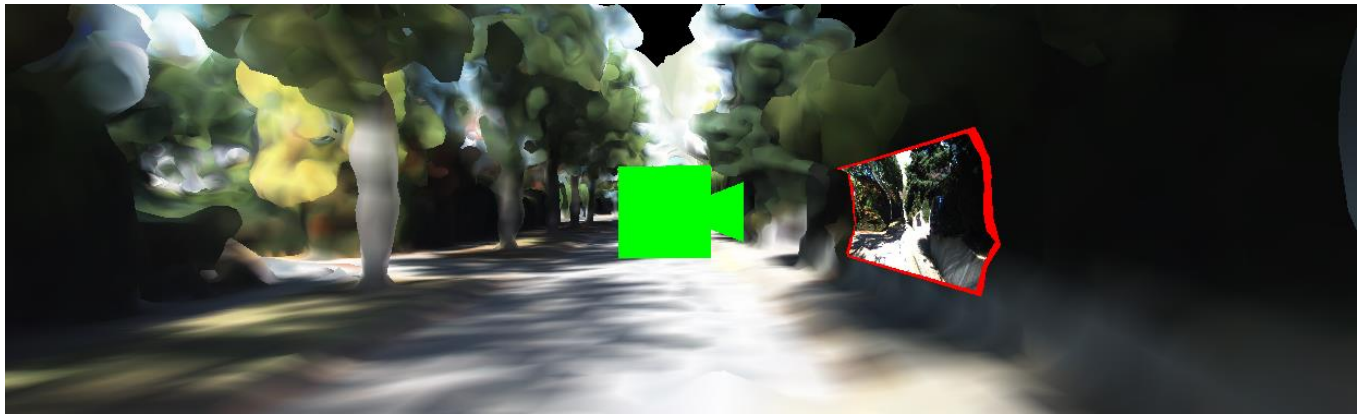
$$P = \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix} \in \mathbb{SE}_3 \qquad (1)$$

Projective Texture Mapping

From the odometry from COLMAP, a pose of the camera is acquired.

This pose is used as a projector position.

The image corresponding to that pose is projected to all the 3D points in front of where that camera was.



Conclusions

- Machine vision methods have enabled a new level of photo-realism to development time ratios.
- Real environments may now be created for simulation based trials so long as they can be recorded on camera.
- Driving simulation has come full-circle from video based driving simulators, to analog and digital environments, and now back to video based simulators.
- The connection between image coordinates and 3D model coordinates allows for interesting modes of analysis. I have a particular interest in connecting this to eye tracking.

Thank you

I will accept any questions you have for me.

Projective Texture Mapping Working Problems

Occluded parts of the scene caused by moving objects result in distortions/visual artefacts.

The further the user strays from the initial path of the recording the worse the synthesised view performs.

Projective texture mapping is a rendering based technique which requires programs to be written to the graphics card in order for it to perform at a reasonable rate.