Representation of the Computer Vision of Autonomous Vehicles using Computer Graphics

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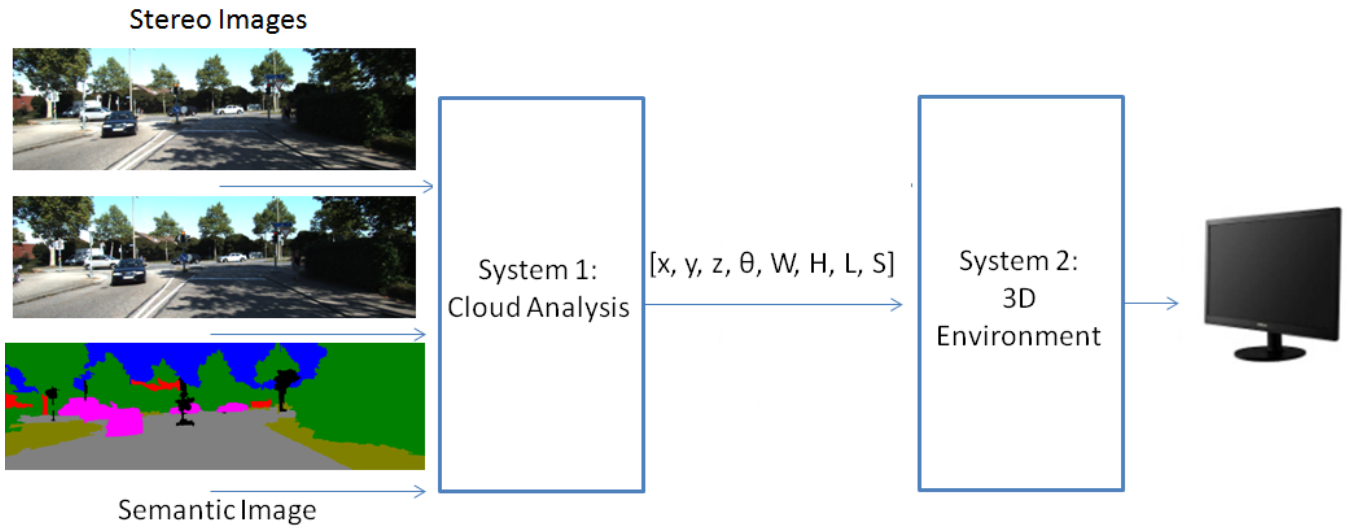
November 23, 2018

Overview

Introduction

- Motivation and Problem
- Objectives

Figure 1: System flowchart



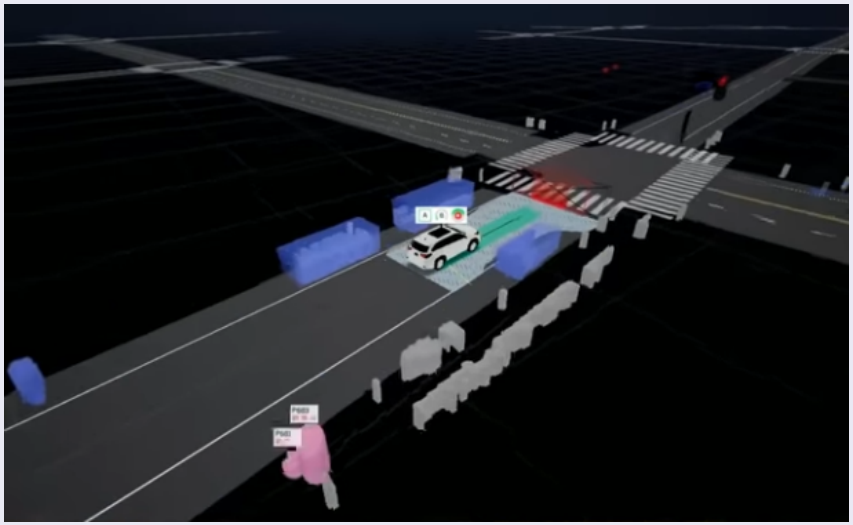
Source: Authors of this study.

State of the Art

Zoox

- Autonomous-driving Startup.

Figure 2: (a) Zoox demonstration car and (b) Zoox simulation environment with route estimation.



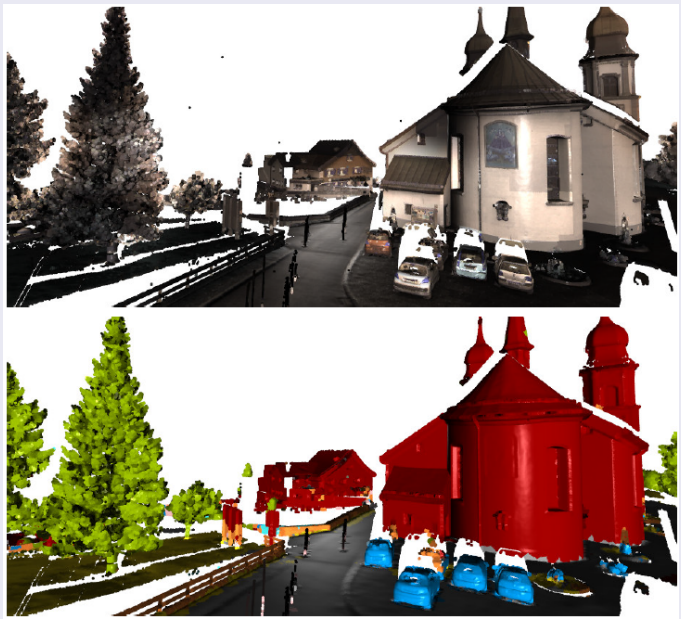
Source: Adapted from [Kentley-Klay, 2017].

State of the Art

Image Segmentation and Depth

- Tangent Convolutions for Dense Prediction in 3D (Intel Labs)

Figure 3: Top: point cloud from the Semantic3D dataset. Bottom: semantic segmentation by the approach.



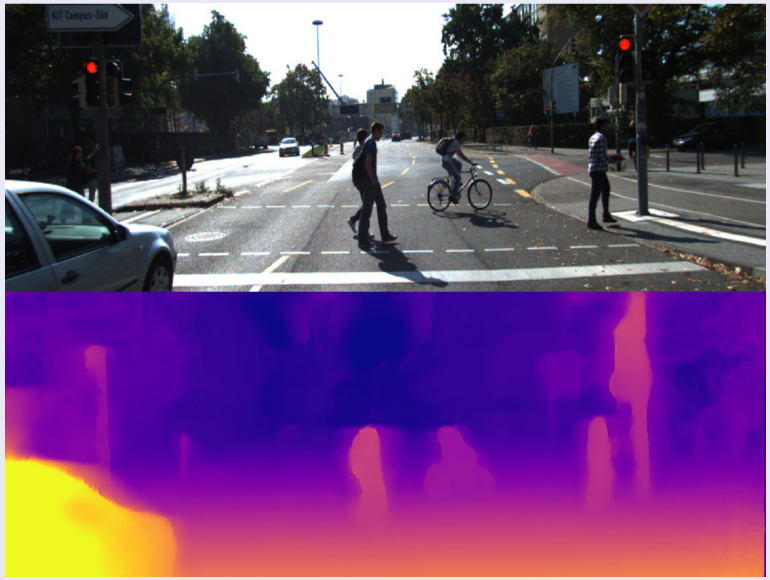
Source: [TATARCHENKO, 2018]

State of the Art

Image Segmentation and Depth

- SuperDepth: Self-Supervised, Super-Resolved Monocular Depth Estimation (Toyota Research Institute)

Figure 4: Trained Monocular disparity estimation network in a self-supervised manner using a synchronized stream of stereo imagery, relieving the need for ground truth depth labels



Source: [PILLAI, 2018]

State of the Art

CARLA

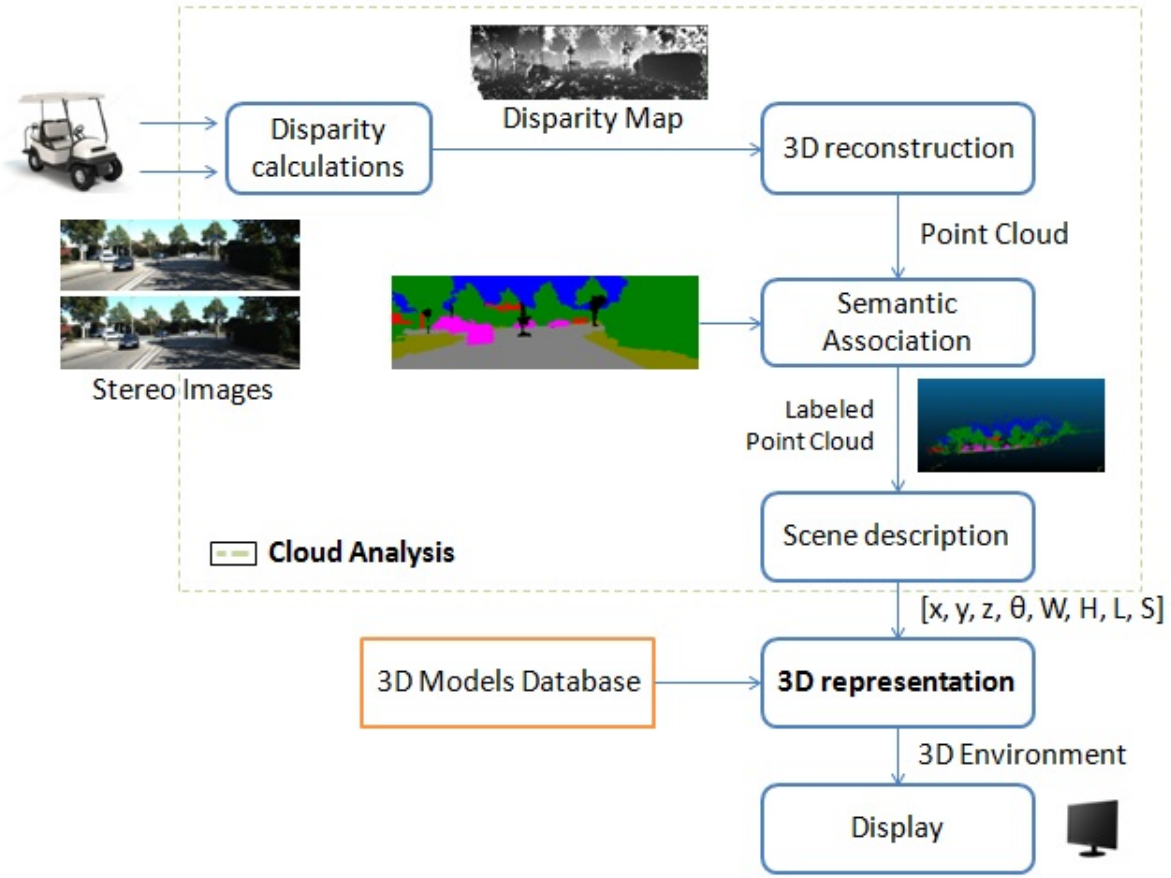
- CARLA: An Open Urban Driving Simulator

Figure 5: Street shown from a third-person view in four weather conditions.

Source: [DOSOVITSKIY, 2017]

Proposal

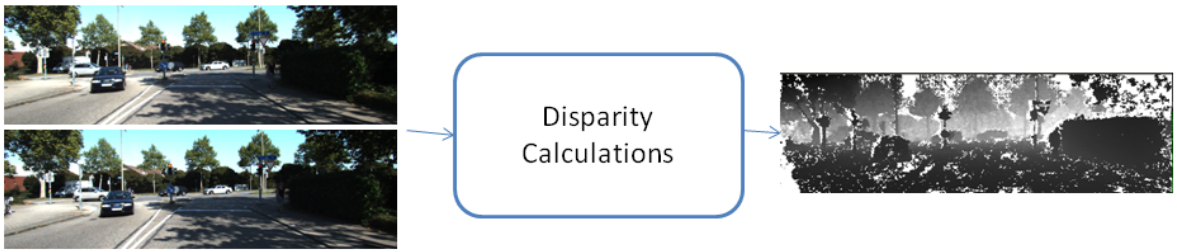
Figure 6: System flowchart



Source: Authors of this study.

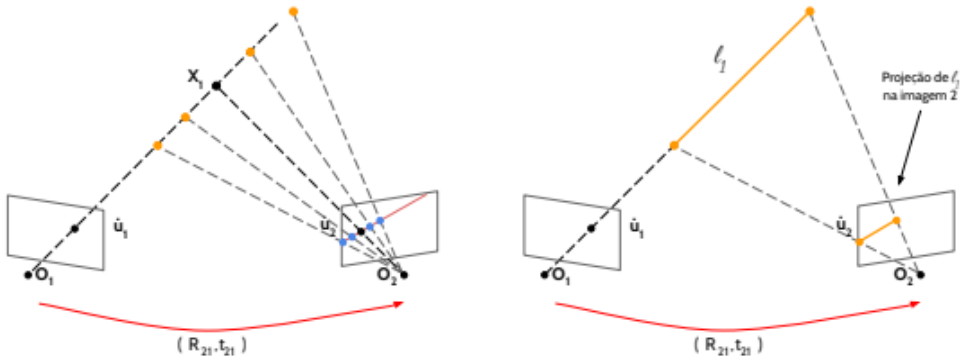
Disparity Calculations Flow

Figure 7: Disparity Calculation Flowchart



Source: Authors of this study.

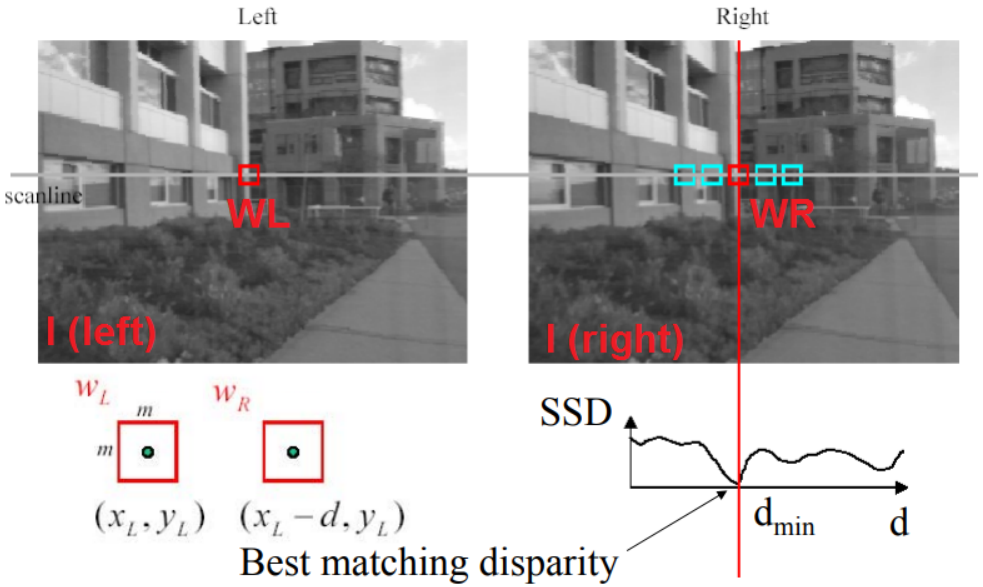
Figure 8: Matching Points



Source: [SILVA, 2016].

SSD and Matching points

Figure 9: Matching Points

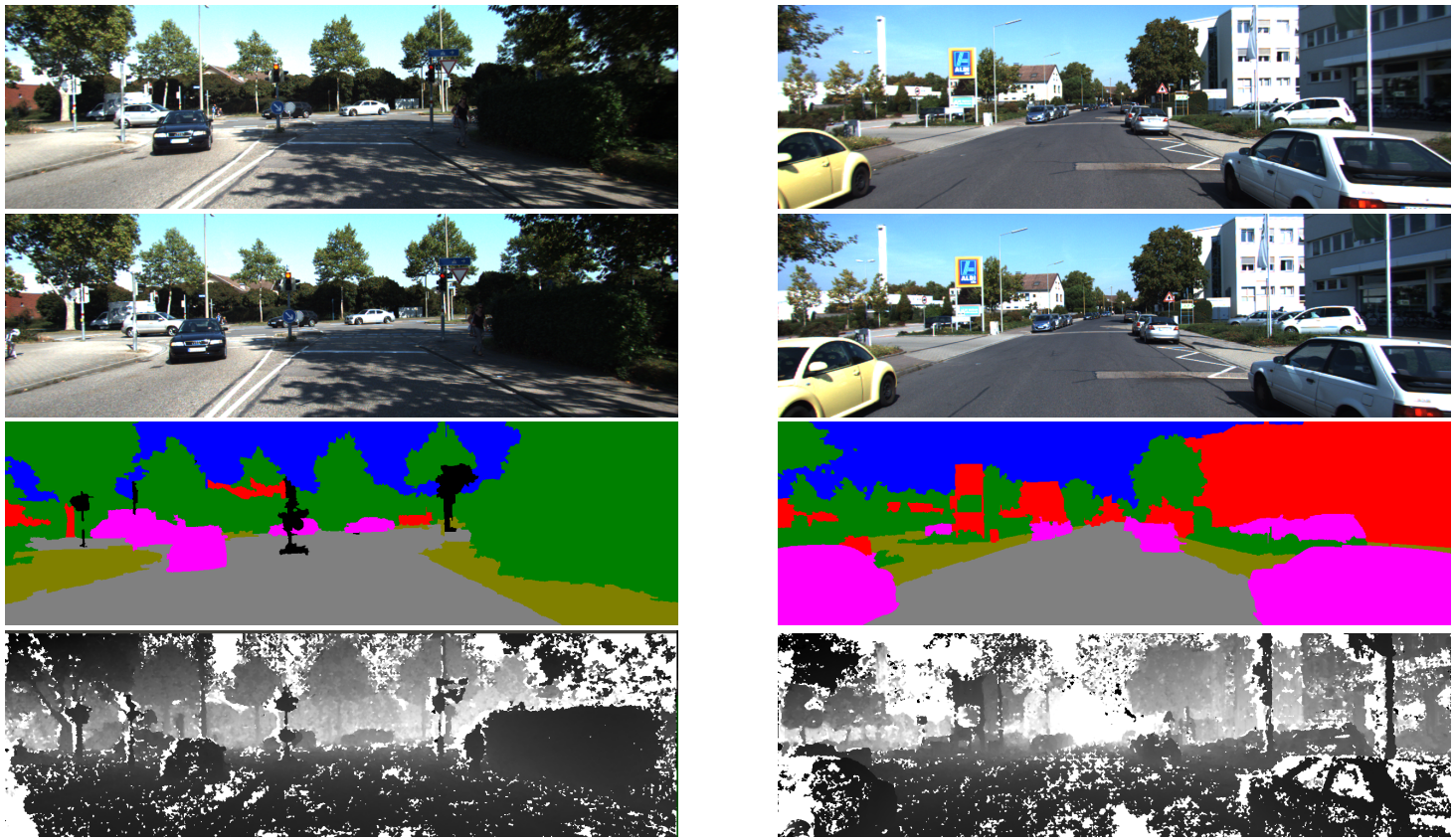


Source: [RAO, 2009].

$$C_r(x, y, d) = \sum_{(u,v)\epsilon W_m(x,y)} [I_l(u, v) - I_r(u - d, v)]^2 \quad (1)$$

Results of Disparity Image

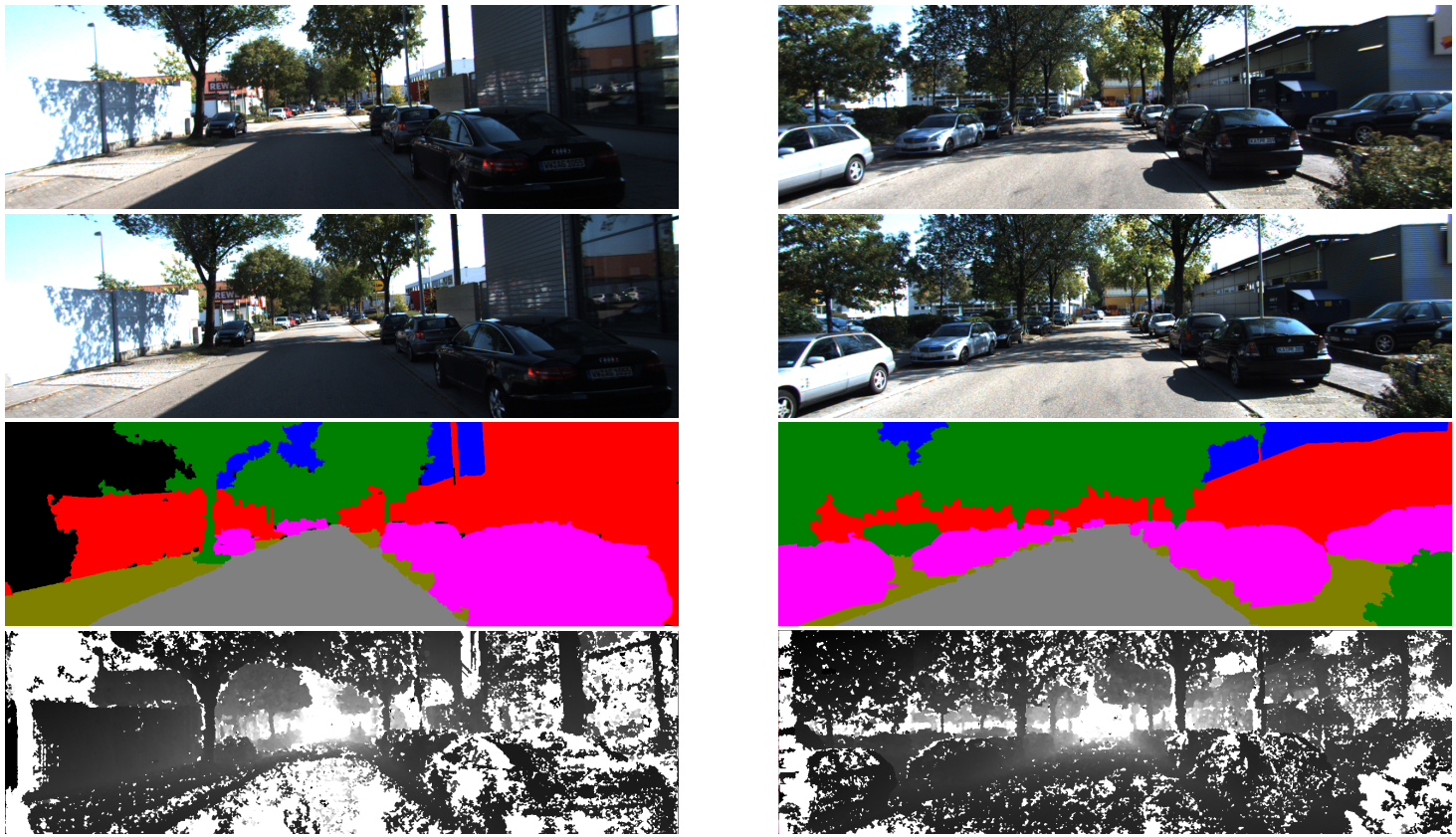
Figure 10: The first and second tests and results obtained for a disparity image generation.



Source: Authors of this study.

Results of Disparity Image

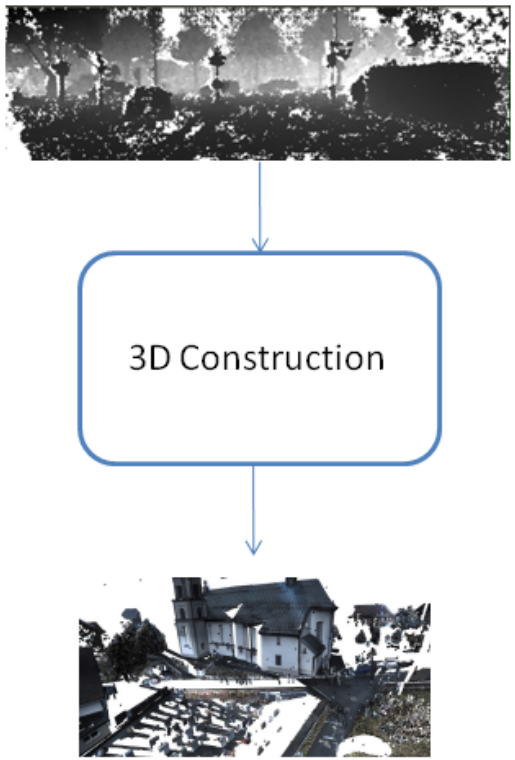
Figure 11: The Third and fourth tests and results obtained for a disparity image generation.



Source: Authors of this study.

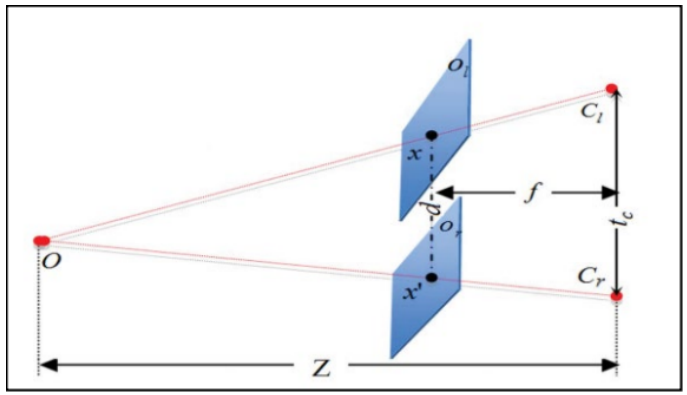
3D Construction

Figure 12: 3D Construction flow



Source: Authors of this study.

Figure 13: Disparity and Depth



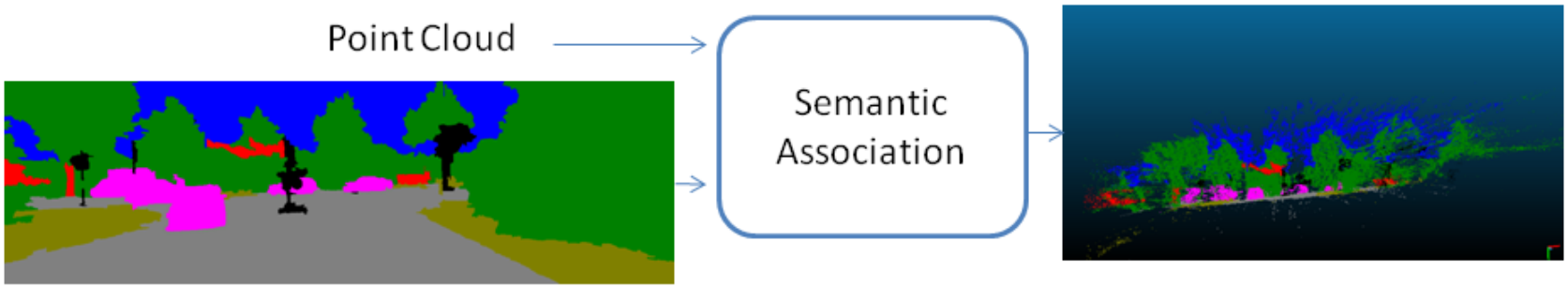
Source: [BATISTA; REGIS, 2013].

$$d = |x_l - x_r| \tag{2}$$

$$Z = \frac{B.f}{d} \tag{3}$$

Semantic Association

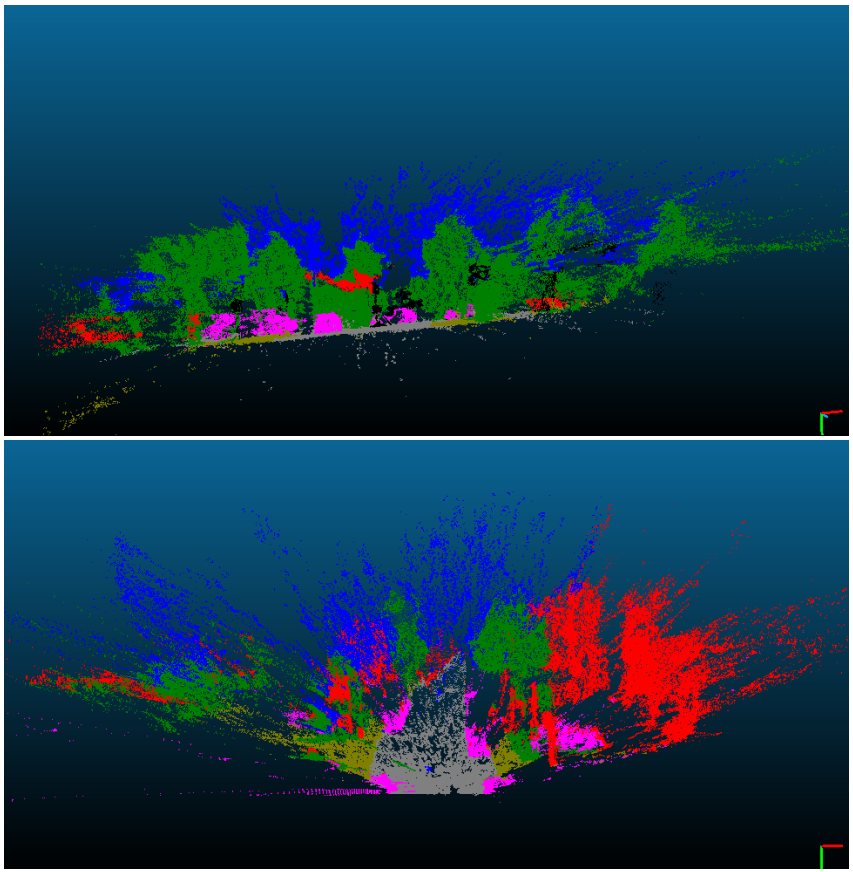
Figure 14: Semantic Image



Source: Authors of this study.

Results of Point Cloud

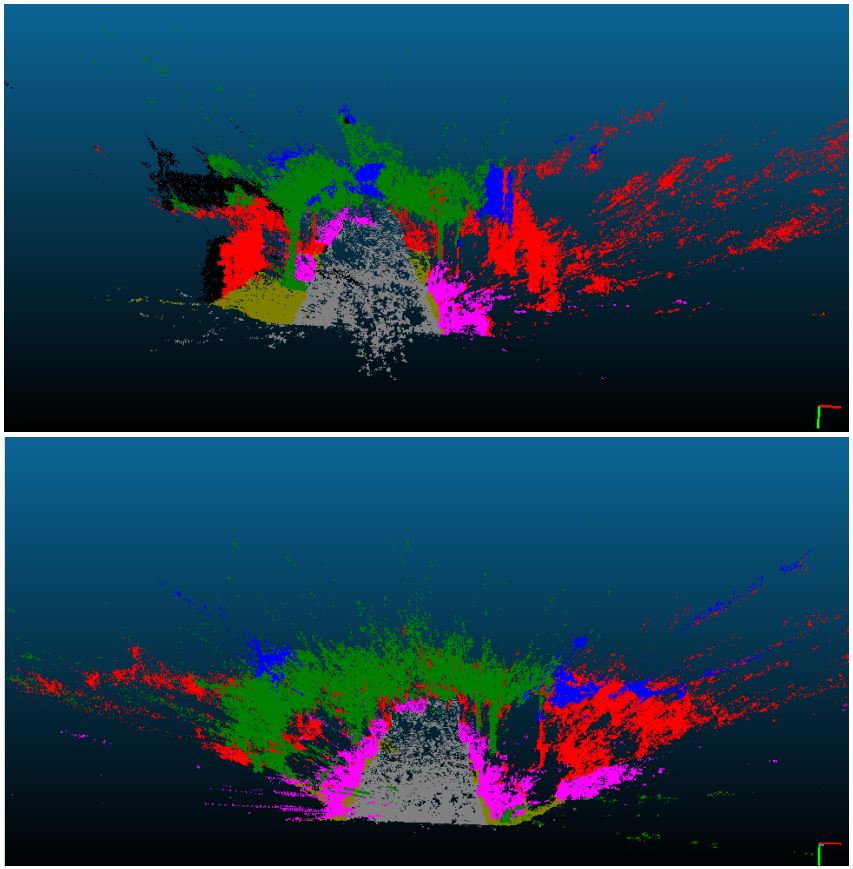
Figure 15: Colored Point Cloud results (First and Second tests)



Source: Authors of this study.

Results of Point Cloud

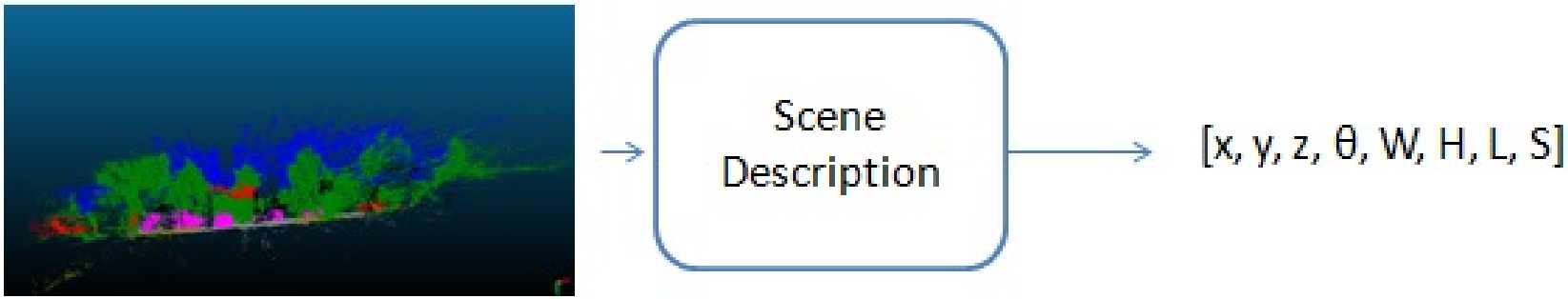
Figure 16: Colored Point Cloud results (Third and fourth tests)



Source: Authors of this study.

Scene Description

Figure 17: Semantic Image



Source: Authors of this study.

Center of mass and Size

Center of Mass

$$x_{mc} = \frac{1}{M}\sum_{i=1}^{n} x_i \qquad (4)$$

$$y_{mc} = \frac{1}{M}\sum_{i=1}^{n} y_i \qquad (5)$$

$$z_{mc} = \frac{1}{M}\sum_{i=1}^{n} z_i \qquad (6)$$

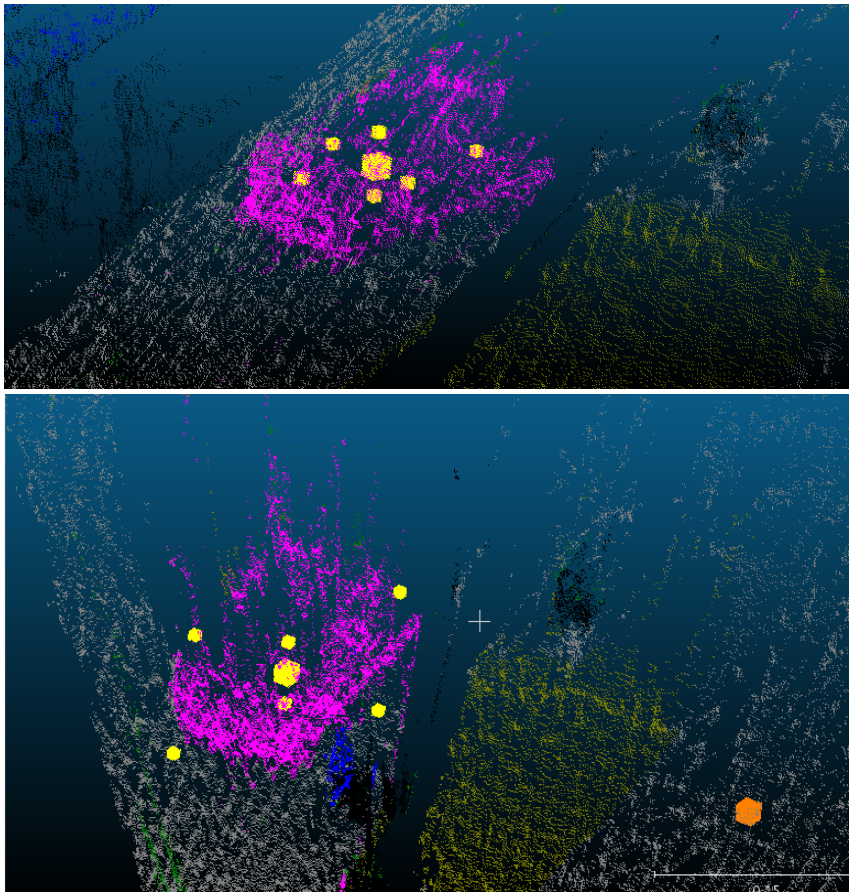
Size of Object

$$\sigma^2 = \sum_{x}(x-\upsilon)^2 f(x) \qquad (7)$$

Sources:
Equations 4, 5 and 6: [HALLIDAY; RESNICK; WALKER, 2009]
Equation 7: [MONTGOMERY; RUNGER, 2011]

Average method vs Variance method

Figure 18: Average method vs Variance method



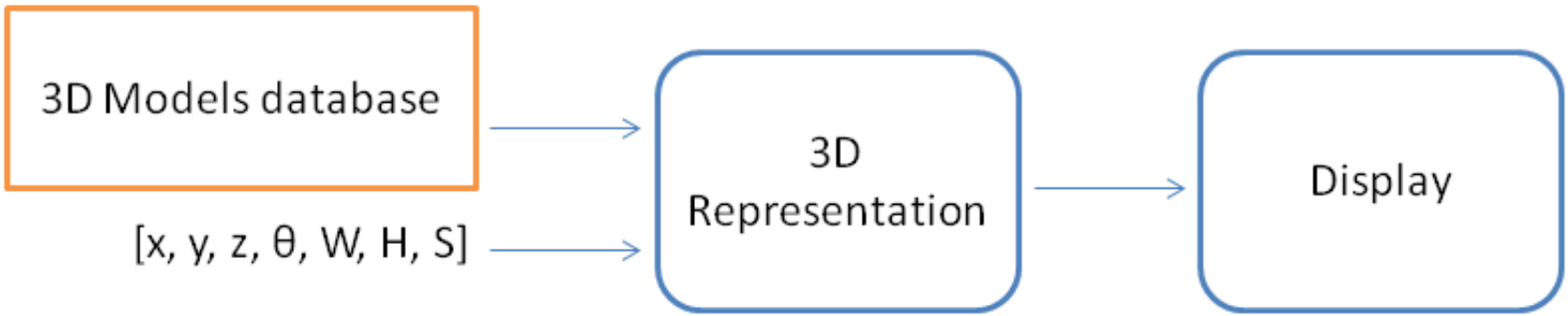
Source: Authors of this study.

Error Analysis

- Camera Calibration
- Low-contrast image regions
- Point Cloud Coordinates

3D Representation

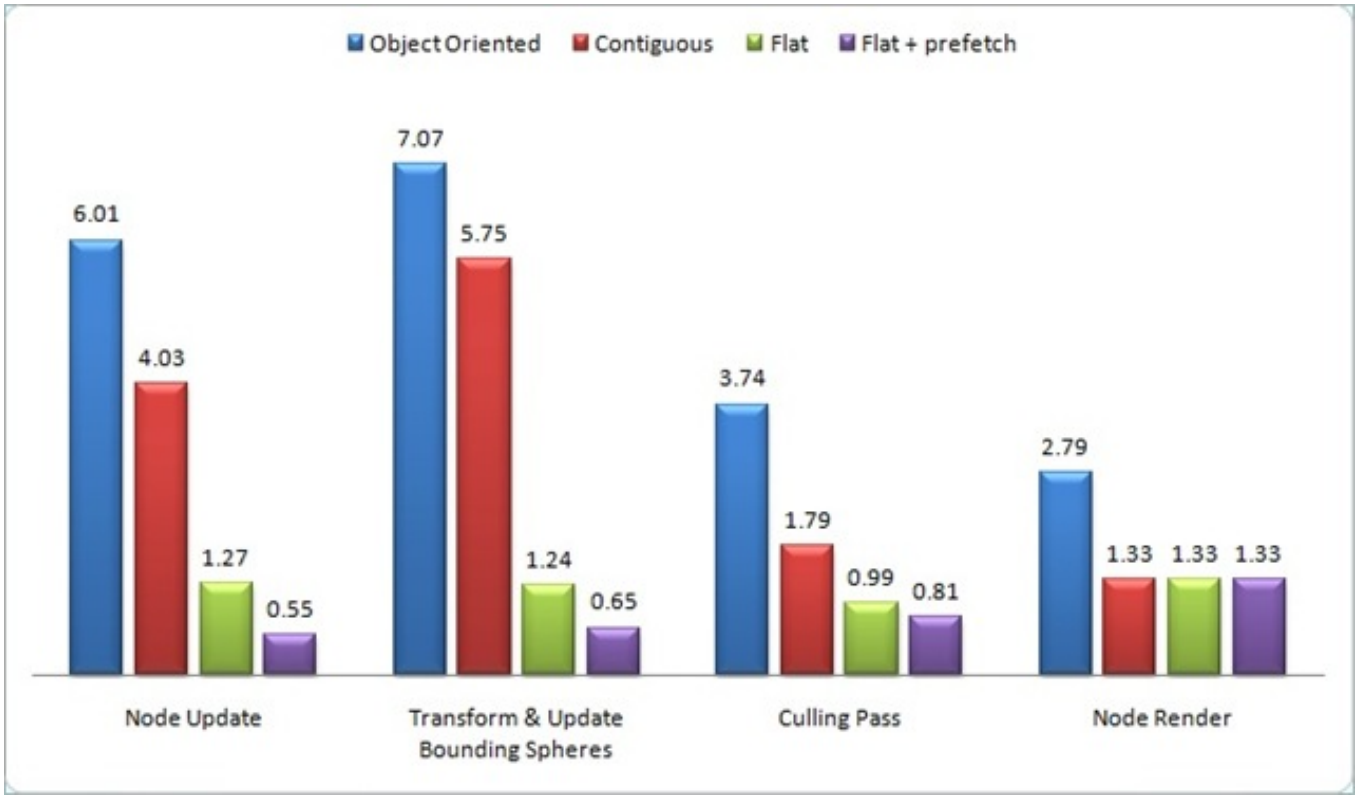
Figure 19: 3D representation flow



Source: Authors of this study.

3D software architecture

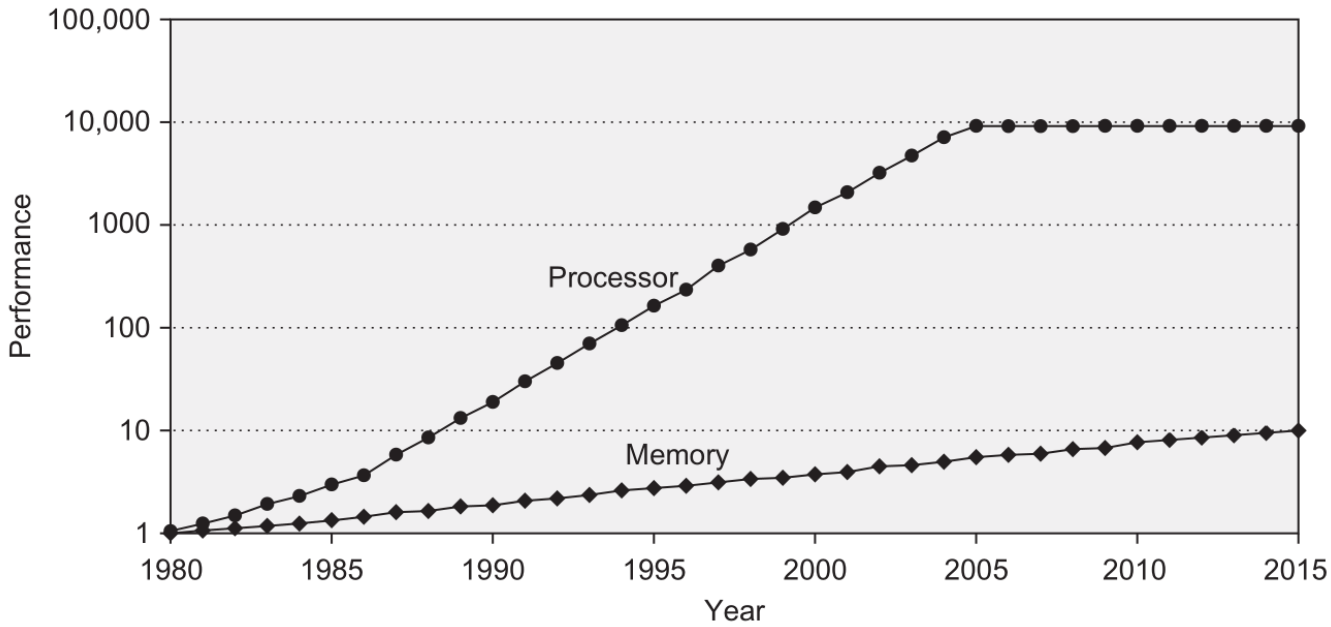
Figure 20: Cache impact of different data design approaches (values in milliseconds).



Source: Adapted from [ALBRECHT, 2009].

Process-Memory Gap

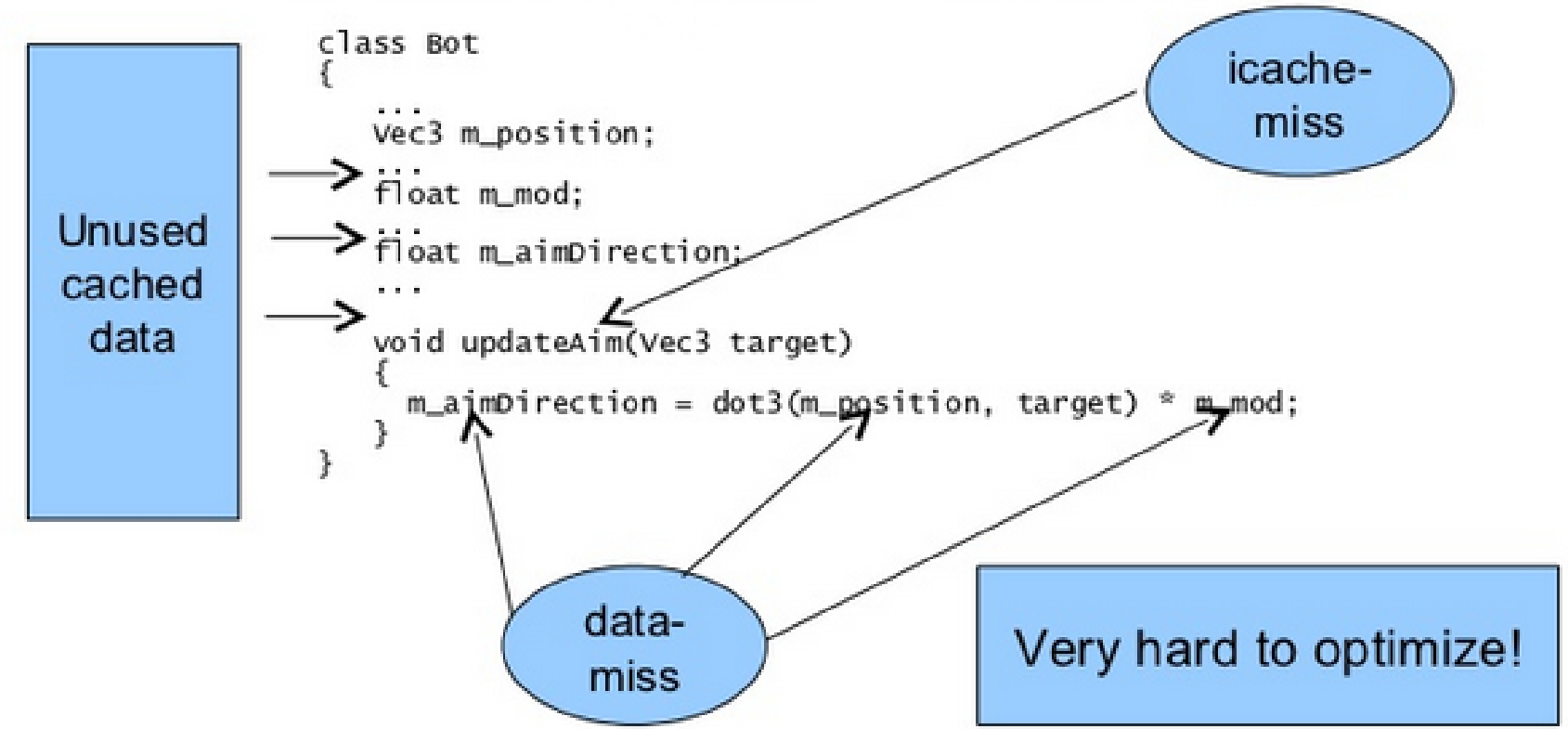
Figure 21: Single processor performance projections against the historical performance improvement in time to access main memory (Processor line shows increase in memory requests per second on average. Memory line shows increase in DRAM accesses per second.)



Source: [HENNESSY; PATTERSON, 2017].

Data Oriented Design

Figure 22: Object-Oriented Programming code example



Source: [COLLIN, 2010].

Data Oriented Design

Figure 23: Data-Oriented Programming code example

```
void updateAims(float* aimDir, const AimingData* aim,
                vec3 target, uint count)
{
  for(uint i = 0; i < count, ++i)
  {
    aimDir[i] = dot3(aim->positions[i],target) * aim->mod[i];
  }
}
```

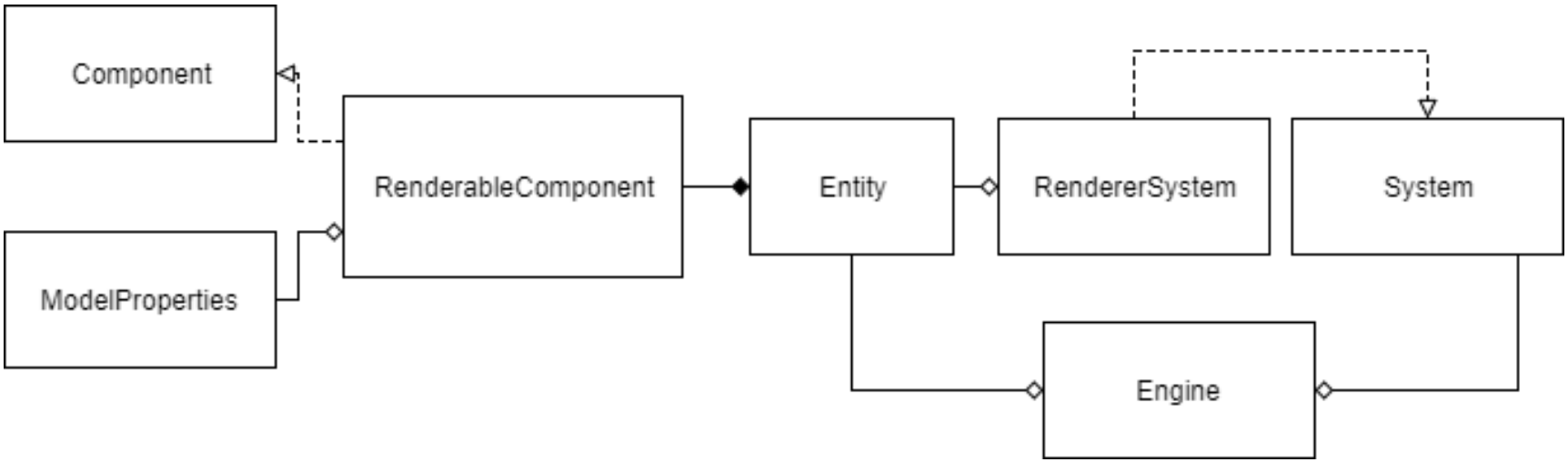
What has changed?

Only read needed inputs	Write to linear array
Loop over all the data	Actual code unchanged
Code separated	

Source: Adapted from [COLLIN, 2010].

Software Architecture

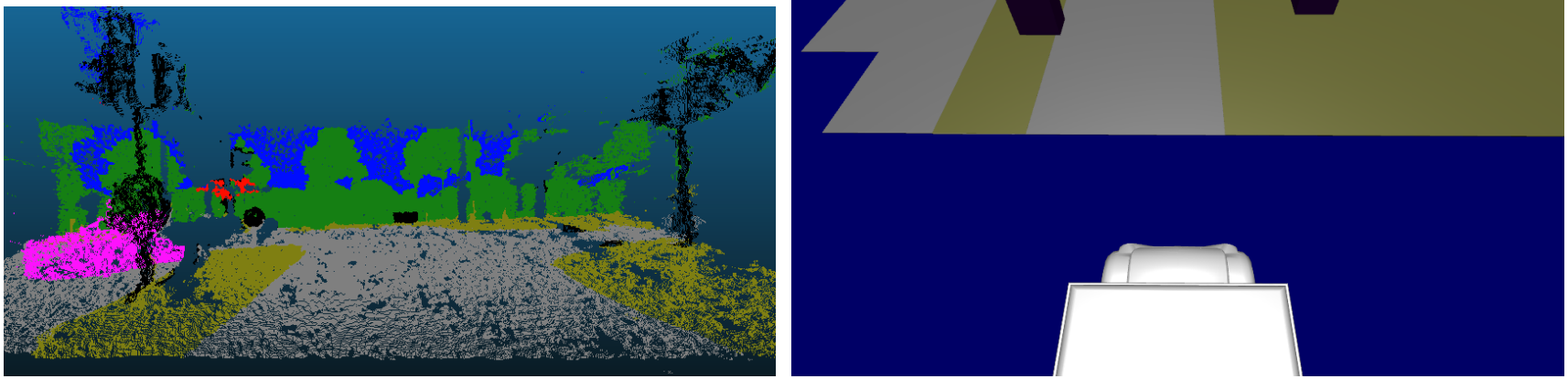
Figure 24: 3D environment simplified diagram



Source: Authors of this study.

Results of 3D environment

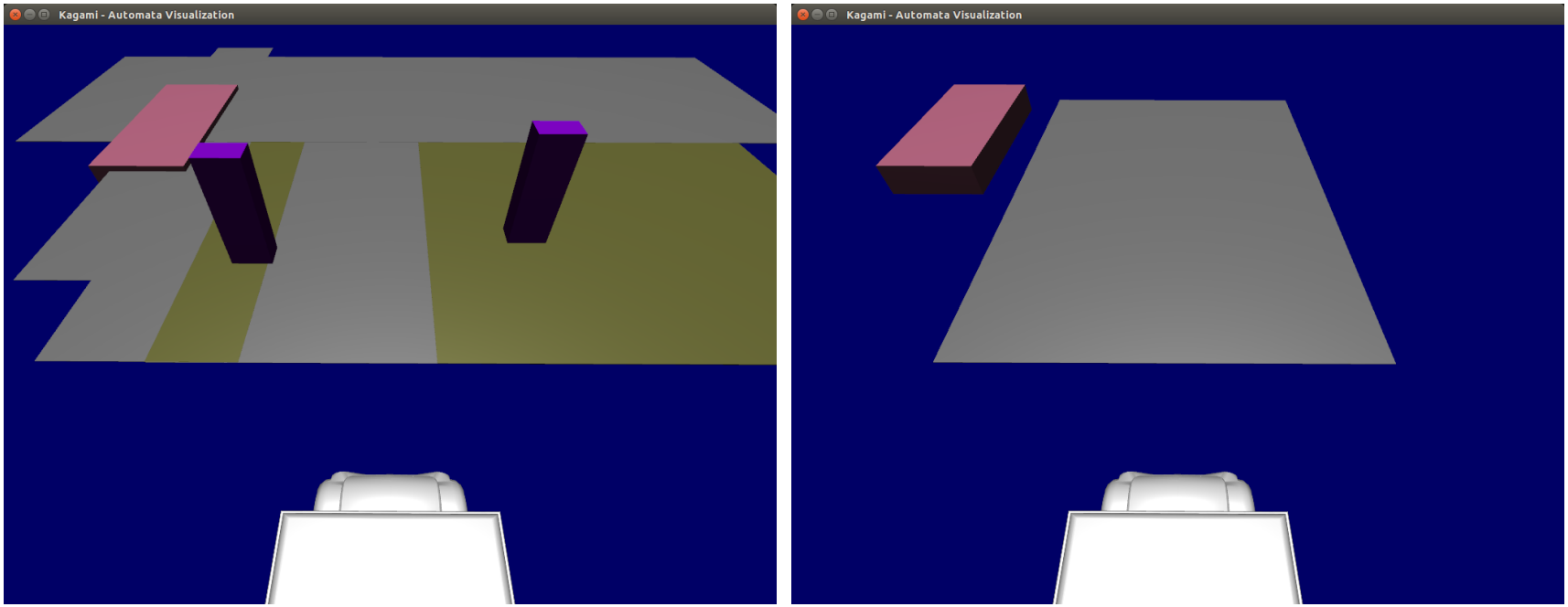
Figure 25: Crafted baseline scene



Source: Authors of this study.

Results of 3D environment

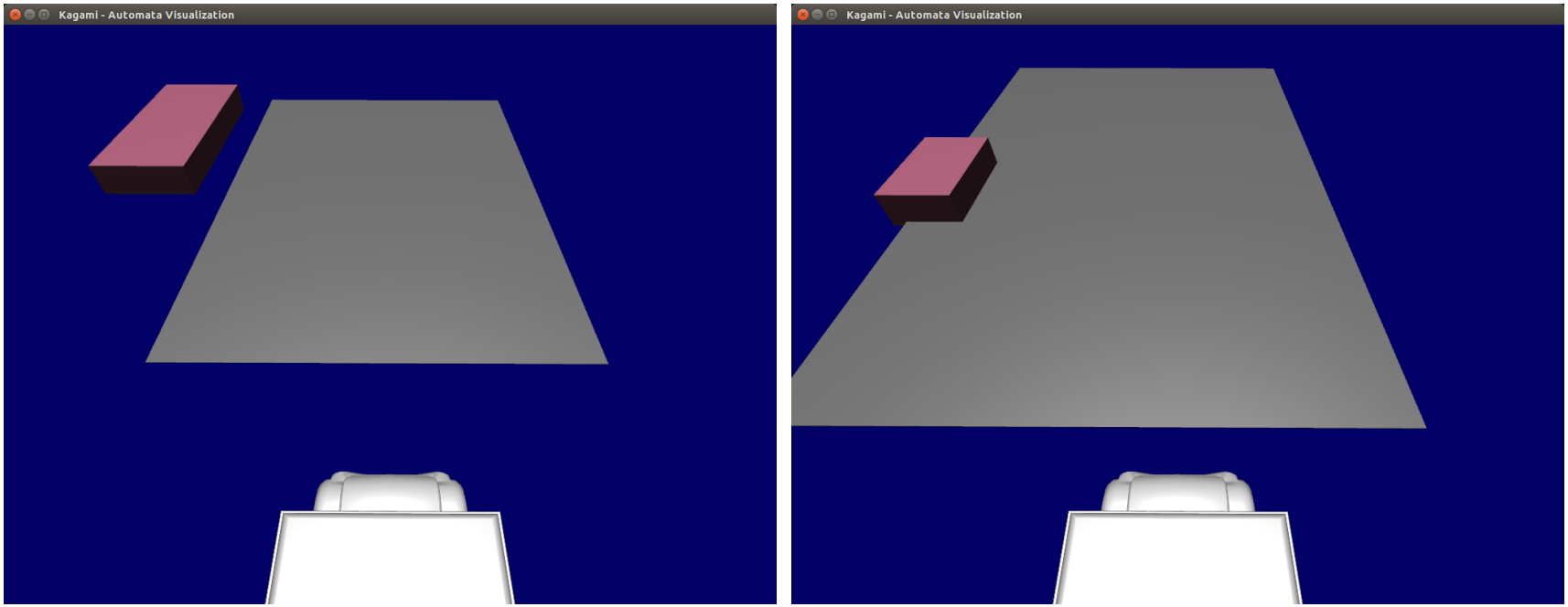
Figure 26: Simplified baseline scene



Source: Authors of this study.

Results of 3D environment

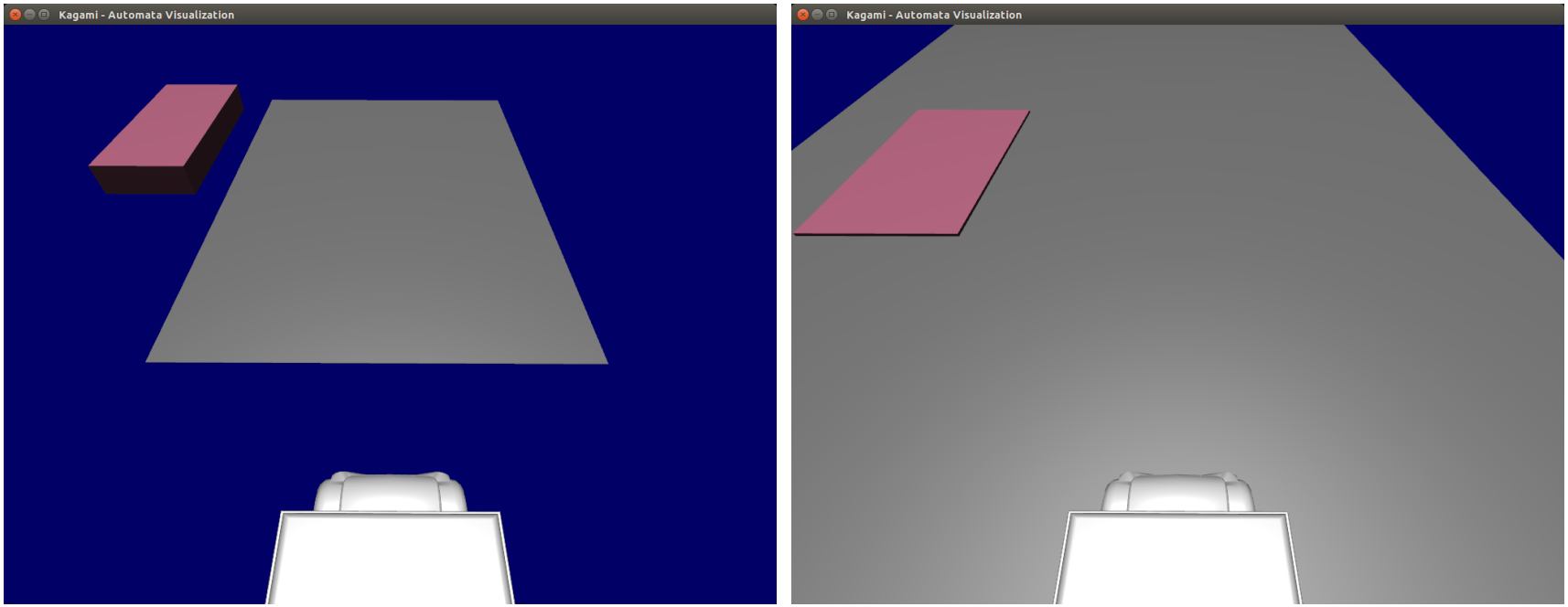
Figure 27: Baseline vs Center of mass method



Source: Authors of this study.

Results of 3D environment

Figure 28: Baseline vs Variance method



Source: Authors of this study.

Final Considerations

- Achieved goals
  - Creation of 3D scenes using Semantic Images and Point Clouds;
  - 3D Environment architecture and development.
- Conclusion
  - End-to-end System;
  - Qualitative results;
  - Limited entities.
- Future Work
  - Feature Extraction with Clustering
  - Depth calculation with Advanced Algorithms
  - Intelligent city web surveillance
  - Artificial Intelligence decision visualization
  - Embedded System prototype performance evaluation

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