Development and Application of a Description-based Interface for 3D Object Reconstruction

Kai Wu

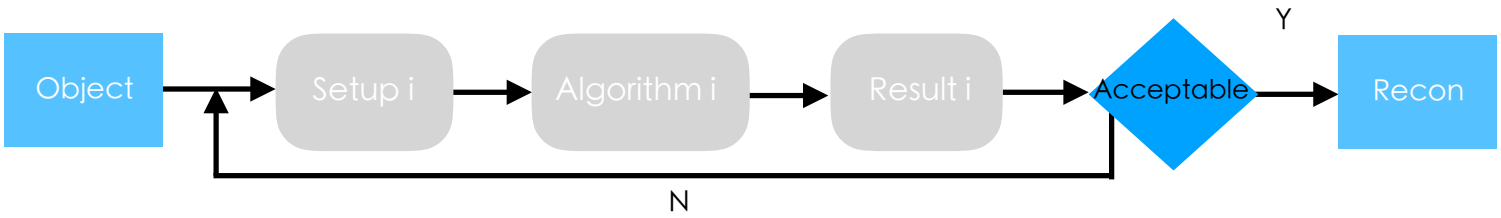
University of British Columbia

kaywu@ece.ubc.ca

October 12, 2017

Table of Contents

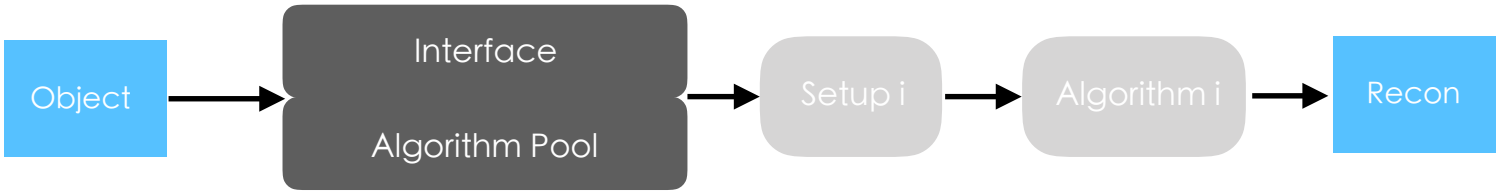
Motivation: traditional 3D Reconstruction



- Hardware setup: calibration, controlled environment
- Algorithms: vision background
- Results: keep trying until an acceptable result

Motivation: interface to 3D Reconstruction

What if we can create an interface above the 3D algorithms, which can select an appropriate algorithm based on users' description, and achieve a successful reconstruction result.



Contribution

Development of an interface for 3D reconstruction problem, which hides algorithmic details and allows users to describe conditions surrounding the problem. This description can be interpreteded so that an appropriate algorithm is chosen to obtain a successful reconstruction result.

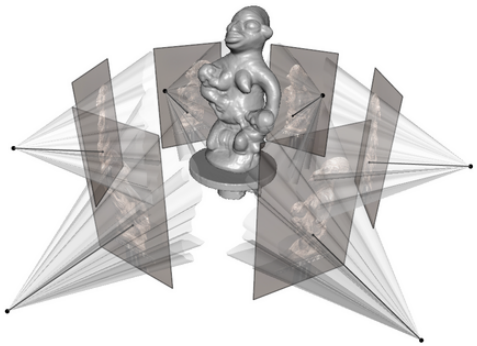
Contribution (cont'd)

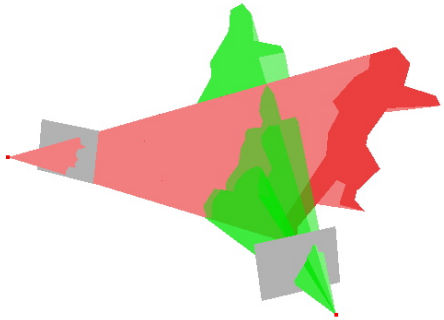
This contribution is significant because:

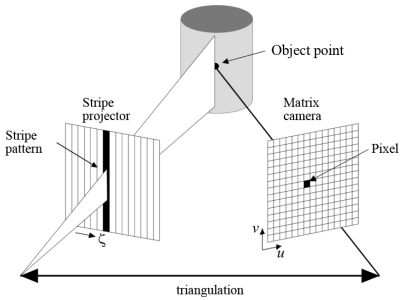
- No single algorithm can work for a diverse categories of objects. The interface, to some extent, can cover a wider range of object categories by incorporating multiple algorithms.
- An description is provides that hides the algorithmic details, thus understanding of the algorithm, or conditions to apply a specific algorithm is not a prerequisite.

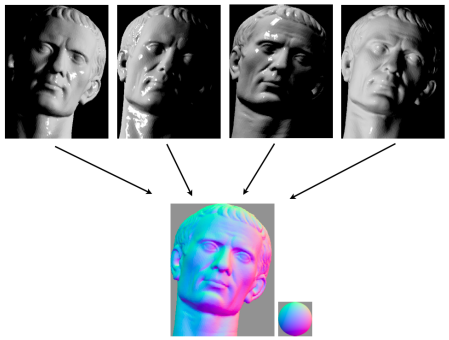
Related Work

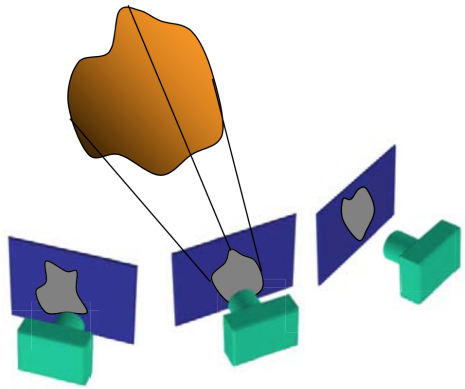
Previous algorithm taxonomy based on visual/geometric cues.







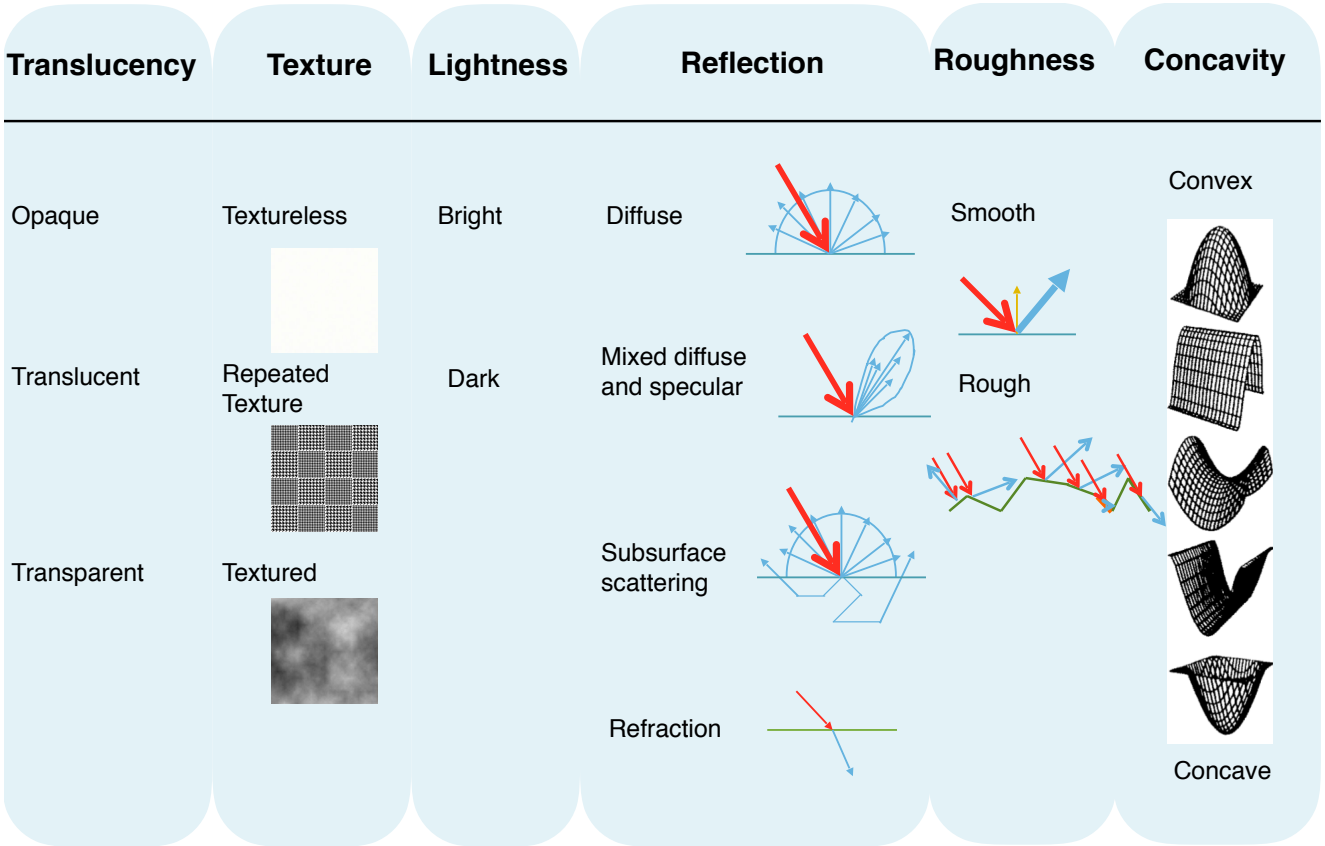




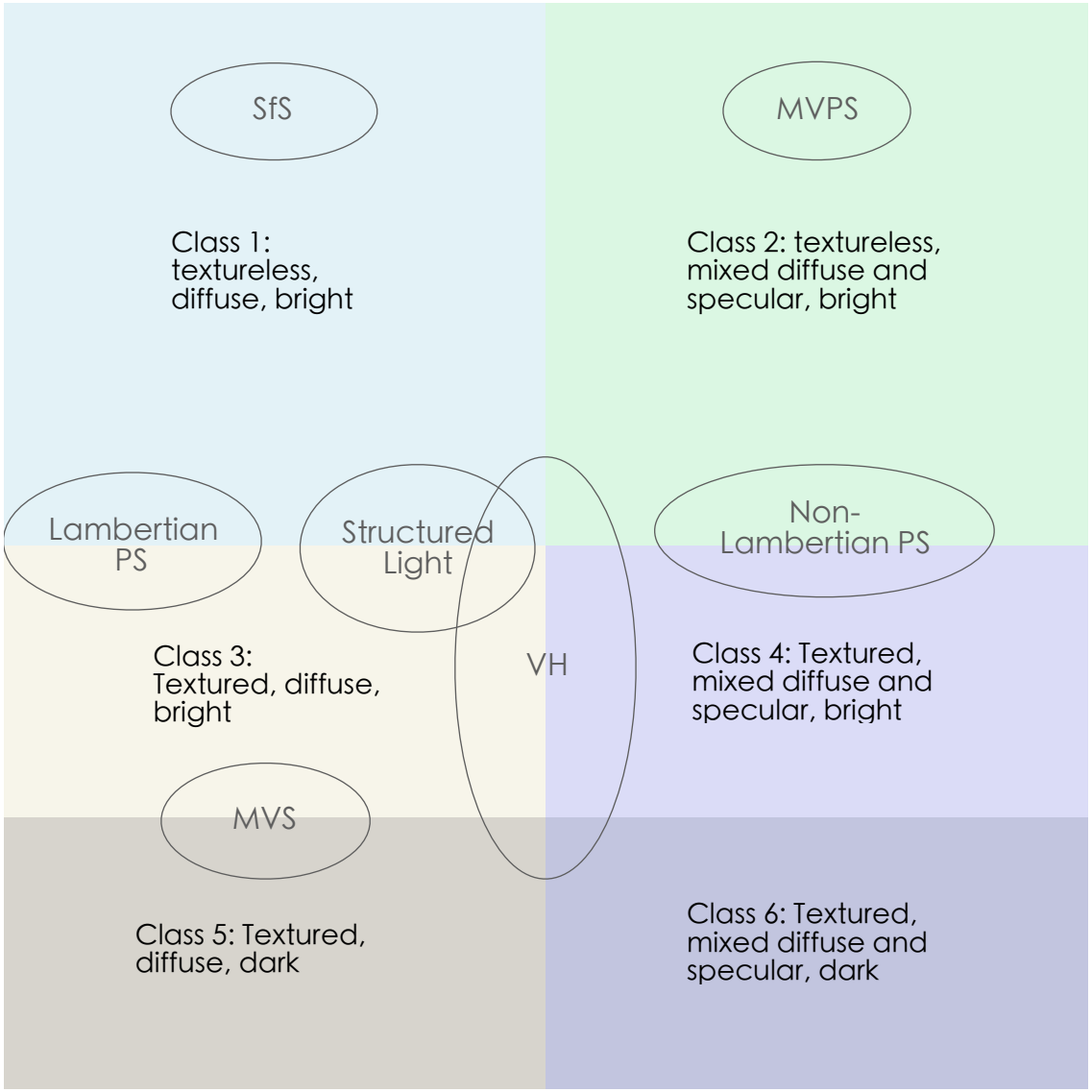
(a). Stereo (b). Shading (c) Silhouette

Taxonomy: properties of problem space

- *algorithm-centered* taxonomy categorizes algorithms based on algorithmic details, as discussed in **Related Work**;
- *object-centered* taxonomy categorizes algorithms based on the problem conditions that the algorithm can reliably works under.



Taxonomy: six problem conditions



Description: model and representations

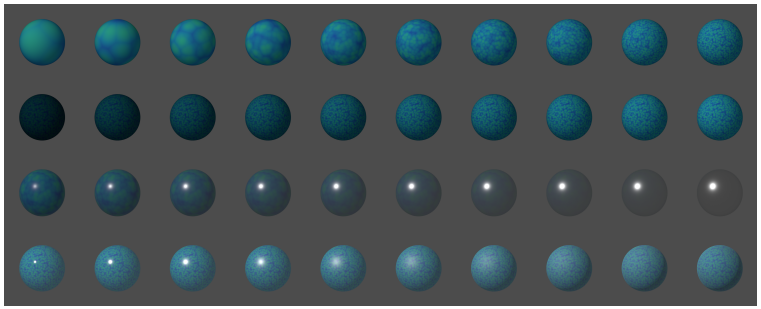
Model	**Representation**	**Visualization**
Texture	*Texture randomness*	
Lightness	*Albedo*	
Specularity	*Specular/diffuse ratio*	
Roughness	*SD of facet slopes*	

Table: Representations of the 3D reconstruction problem.

Description: expression

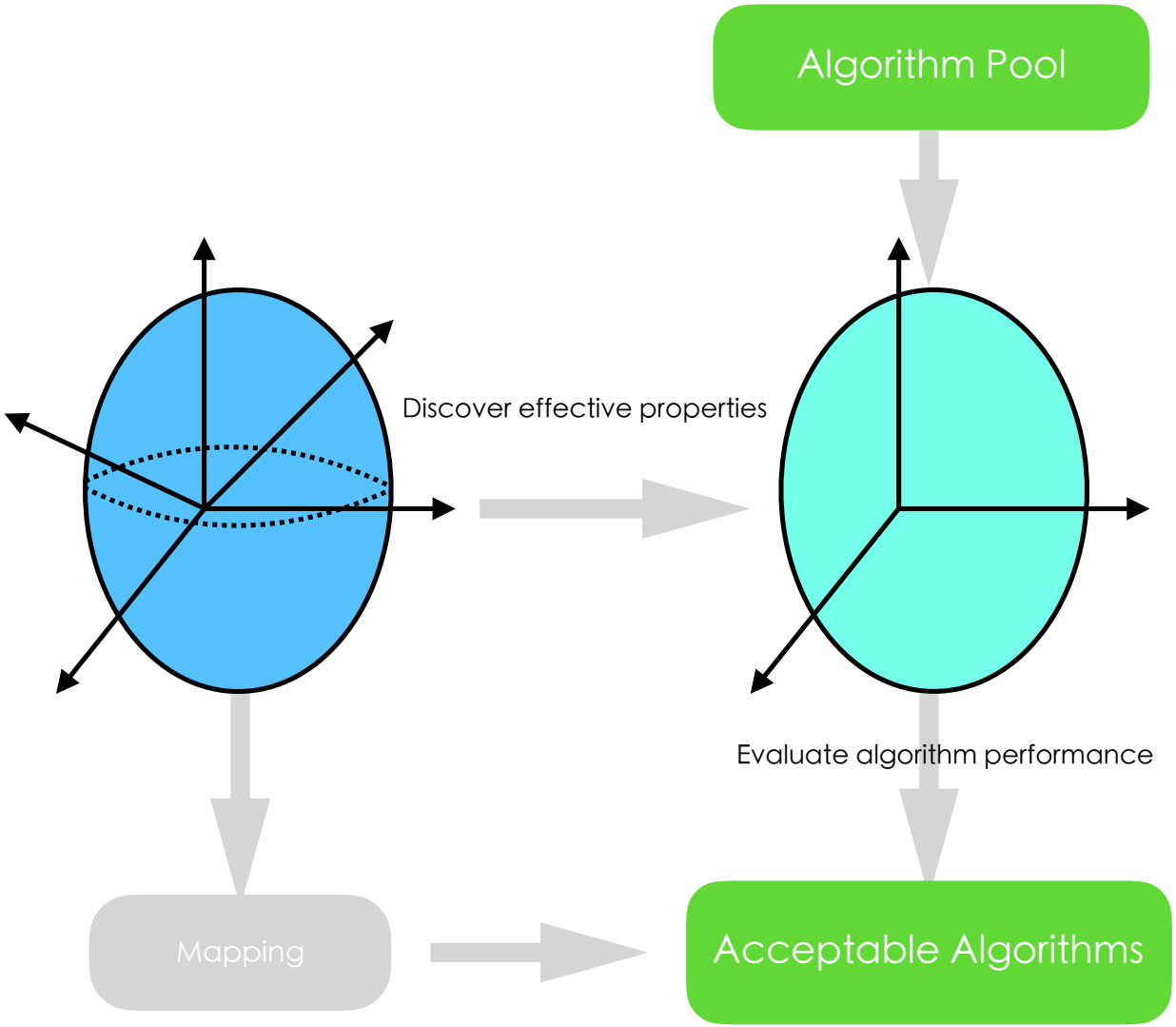
We use three discrete scales to parameterize these properties: *low* (0.2), *medium* (0.5), and *high* (0.8).

Object	Texture	Albedo	Specular	Rough	**Label**
Class 1	low/med	high	low/med	high	TI-B-D-R
Class 2	low/med	high	high	low/med	TI-B-M-S
Class 3	high	high	low/med	high	T-B-D-R
Class 4	high	high	high	low/med	T-B-M-S
Class 5	high	low/med	low/med	high	T-D-D-R
Class 6	high	low/med	high	low/med	T-D-M-S

Table: Expression of the reconstruction problem for the object classss.

Mapping

Investigate the problem conditions under which the algorithms can reliably work. This strucure of this chapter is as follows



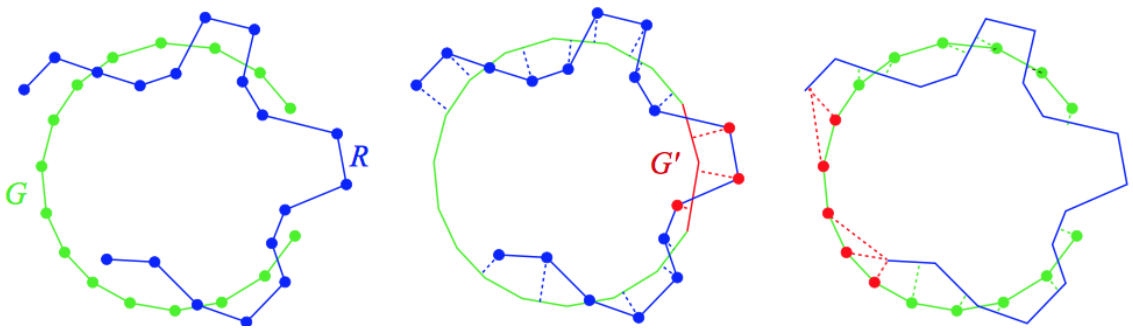
Mapping: algorithms and baseline

Technique	Texture	Albedeo	Specular	Roughness
PMVS: patch-based, seed points propagation MVS.	High	-	Low	-
EPS: example-based Photometric Stereo	-	High	Low	High
GSL: Gray-code Structured Light technique	-	High	Low	High
VH: volumetric Visual Hull.	-	-	-	-
LLS-PS: linear least squares Photometric Stereo.	-	High	Low	High

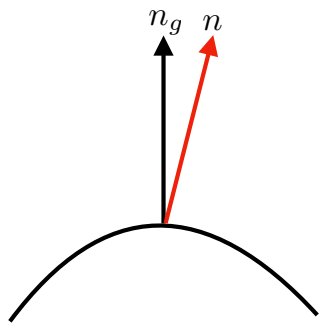
Table: Summary of the selected and baseline algorithms.

Mapping: quantitative measures and criteria

- accuracy: the distance d such that $X\%$ of the points on R are within distance d of G is considered as accuracy;
- completeness: the percentage of G that is reconstructed by R;
- angular error: angle between the estimated and ground truth normal, *i.e.*, $arccos(n_g^T n)$.



Accuracy and completeness



angular error

Interpretation: Key Evaluation Questions

- Evaluation of mapping: is the mapping robust to changes of shape?
- Evaluation of interpreter: can the proof-of-concept interpreter return a successful reconstruction given the correct description?

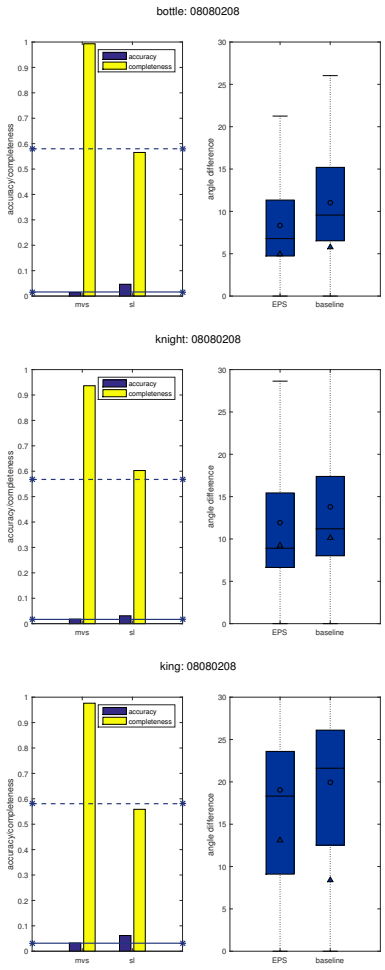
Interpretation: evaluation of mapping

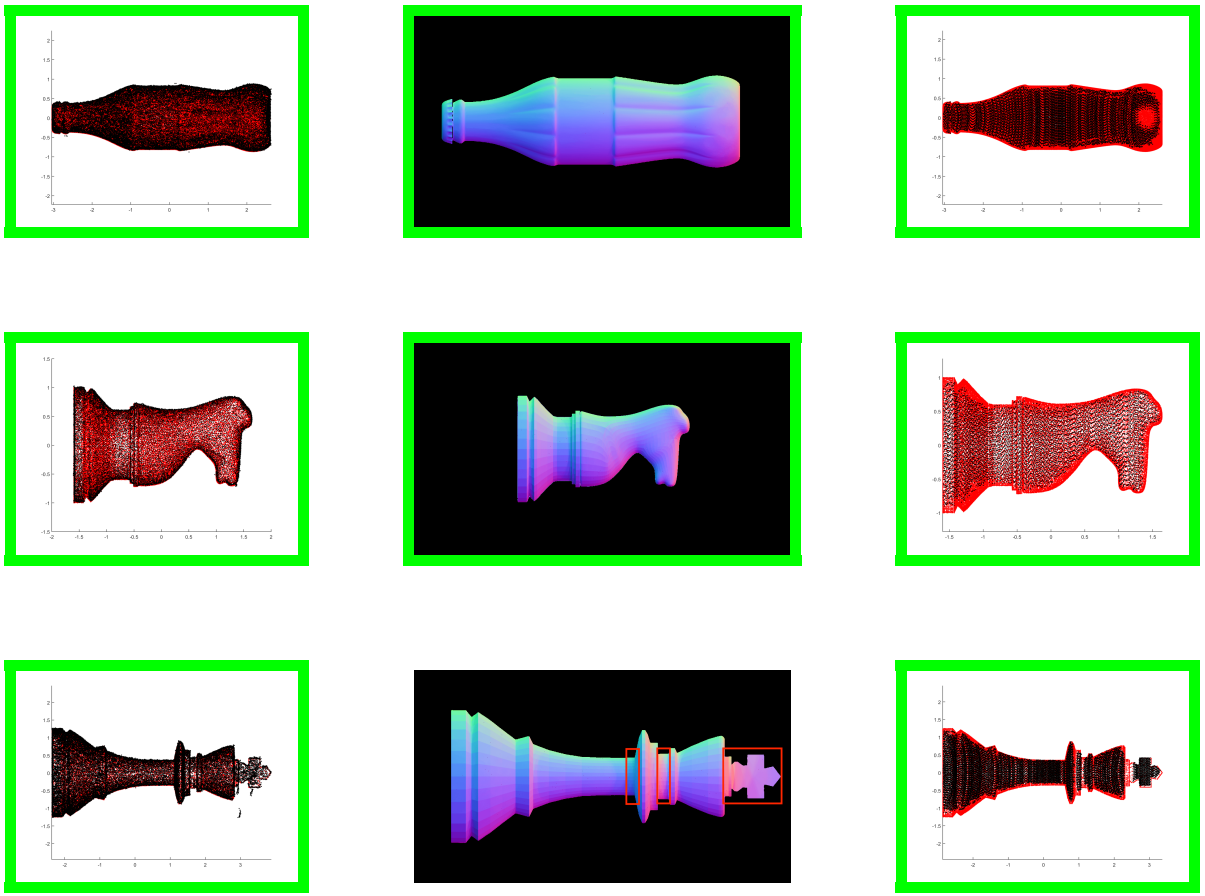
- Shape variation: too vast and complicated to model;
- Instead focus on one geometric property: surface concavity, and see how robust is the mapping with respect to concavity changes.

Interpretation: evaluation of mapping (cont'd)

Quantitative results

Qualitative results





PMVS EPS GSL

Figure: Problem condition: 08080208, mapped algorithms: PMVS, EPS, GSL.

Interpretation: evaluation of mapping (cont'd)

Conclusion:

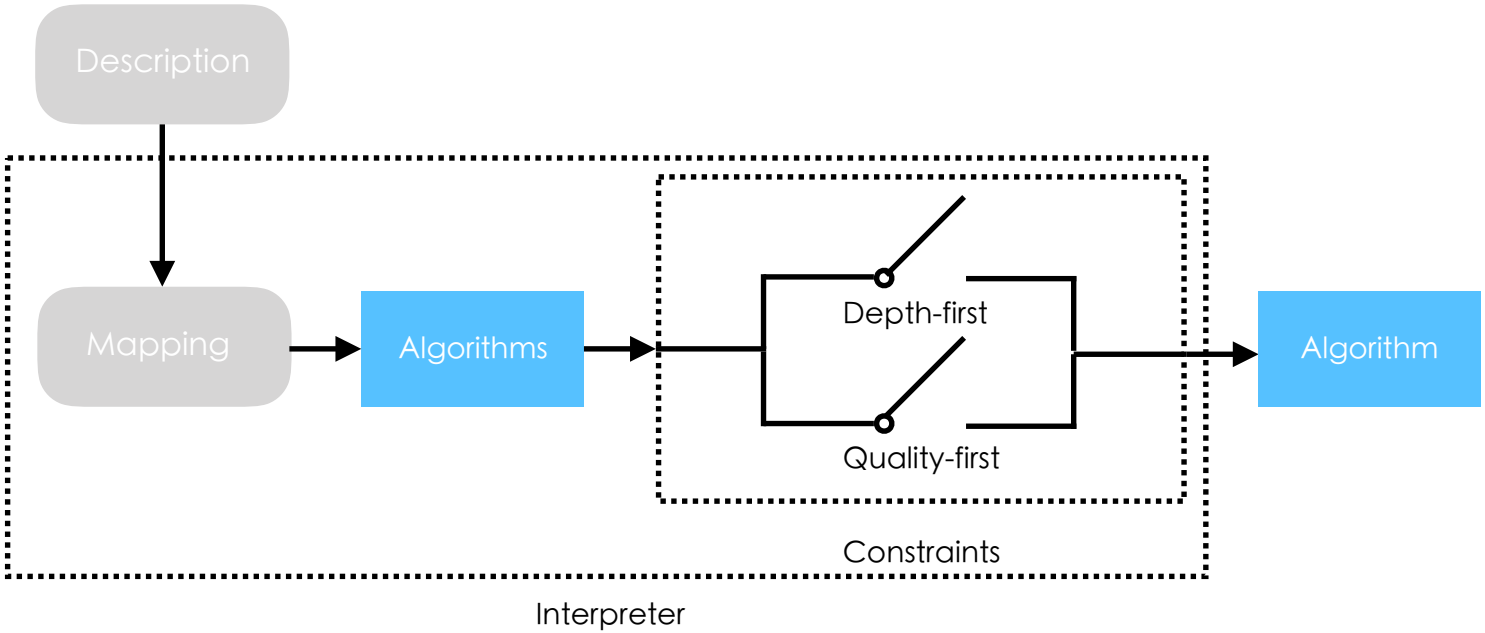
- Mappings to PMVS and GSL are robust to concavity changes whereas those to EPS are not.

Suggestions:

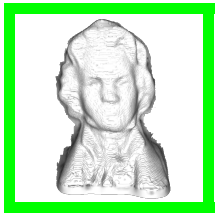
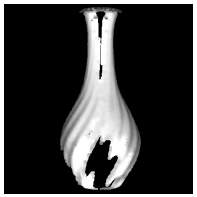
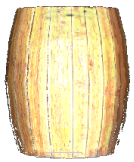
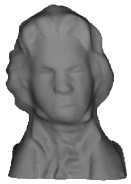
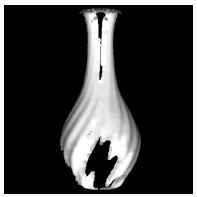
- Develop more advanced description, incorporating concavity into the description
- Use more underlying algorithms that are robust to concavity changes.

Proof-of-concept interpreter

An interpreter selects an appropriate algorithm based on description of problem condition and constraints.



Interpretation: evaluation of interpreter

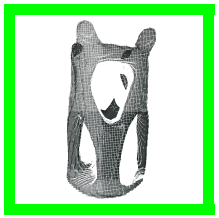
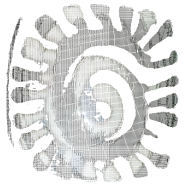
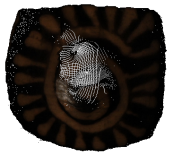
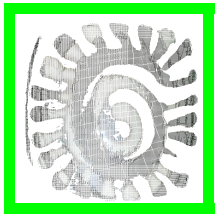
Desc #	Bust	Vase1	Barrel	Vase0	Selected Algo.
1					GSL
2					EPS
3					GSL
4					PMVS

Interpretation: real-world objects

class #	1	2	3&4	5&6
description	textureless diffuse bright	textureless mixed d/s bright	textured diffuse dark/bright	textured mixed d/s dark/bright
object				

Figure: The rerepsentatives of the six classes of objects used for evaluation.

Interpretation: evaluation of interpreter (cont'd)

Desc #	Statue	Cup	Pot	Vase	Selected Algo.
1					GSL
2					EPS
3					GSL
4					PMVS

Conclusions

- Using the simple descriptive language and proof-of-concept interpreter, we demonstrate the possibility of using descriptive properties to hide algorithmic details.

Take-away message

Computer vision should focus on more than just algorithms, but easier accessibility.