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sentation of a facade and regularise windows and doors using 'snap-line' techniques [Müller et al. 2007]. Although this often works for Manhattan-style facades, irregular facades (such as the church-face in fig. 1), require data-driven algorithms. The key challenges in facade-reconstruction are segmentation and polygonisation.

2 The Algorithm

The section presents the algorithm used to reconstruct the facade in figure 1 and those illustrated in the results. The steps are simple:
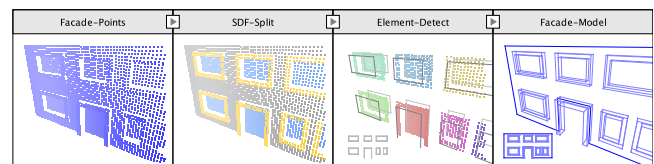
Figure 2: *Key stages in ground facade reconstruction - (left to right): input unstructured point-cloud, signed-distance-field split, segmented surface-element rails, and the resultant facade model.*

Figure 3: *Intermediary data exploited by the ARROW algorithm to produce the result displayed in figure 1 - illustrating (from left to right, top to base) quantized wall-point filter response, binary division resulting from the SDF-split (wall-points in gray, deviant-points in blue), KD-tree used to 'chunk' sets of deviant points, connected component clusters extracted from KD-tree chunks, railed surface-element models, and finally quad-dominant wall model.*

The key idea is to efficiently slice each facade into two sets of points (one containing facade points the other containing salient feature points). Then to cluster each locale of salient points based on connectivity (disjointness). To ensure efficient point-location queries

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Abstract

This simple paper describes an intuitive data-driven approach to reconstructing architectural facade models from unstructured point-clouds. The algorithm presented yields sparse semantically-rich models that are better suited to interactive simulation than the equivalent dense-reconstructions, yet executes significantly faster than the prevalent sparse-operators. The key advantages include accuracy, efficiency and the ability to model irregular windows.

Keywords: laser scanning, LiDAR, architectural reconstruction, procedural modelling, window detection, pointset segmentation

Concepts: •Computing methodologies → Shape modeling; *Object detection; Reconstruction;* Point-based models;

## 1 Introduction and Motivation

The aim this method is to recover compact 3D geometric models of facades that can be used within interactive visualisations and simulations of the real-world. The key limitations of current data-driven facade reconstruction methods are the quality of the generated geometry, and the associated execution times [Musialski et al. 2013]. However methods that exploit model-based templating strategies (although yielding cleaner meshes) are subject to the loss of geometric accuracy and further are constrained by the primitives present in the 'model-library' or 'knowledge-base' [Szeliski 2010]. In such cases it is common to exploit a 2D-split-logic representation of

the operator exploits a simple AABB spatial optimisation and a KD tree space partitioning. Figures 2 and 3 illustrate the key stages and the intermediary data used by the operator. The following pseudo-code seeks to clarify the lower-level behavioural characteristics.

ARROW → **A**ccurate **R**ailed **R**econstruction of **O**penings & **W**alls

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function RECONSTRUCT($pointset, sdf\_offset$)

$p \leftarrow pointset$
$d \leftarrow sdf\_offset$
if $(p \equiv null | p.points \equiv null | p.points.length = 0)$ **then**
  return $null$;
end if
$sdf\_split \leftarrow signed\_distance\_field\_split(p, d)$
$wall\_points \leftarrow sdf\_split[0]$
$deviant\_points \leftarrow sdf\_split[1]$
$elem\_clusters \leftarrow connected\_comps(deviant\_points)$
$elems \leftarrow \{\}$
for $ptset : elem\_clusters$ **do**
  $se \leftarrow railed\_surface\_element(ptset)$
  if $se \neq null$ **then**
    $elems.add(se)$;
  end if
end for
$wall\_mesh \leftarrow sparse\_cutout\_wall(wall\_points, elems)$
$merged\_elems \leftarrow surface\_elements\_to\_mesh(elems)$
$facade \leftarrow \{wall\_mesh, merged\_elems\}$
return $facade$
end function

Two key insights enable the efficient recovery of sparse-geometry. Foremost the operator uses polygon clipping and 3D-sweeps in order to control the topology of facade models. Further by localising on each facade's wall, the operator can project the 3D points onto a 2D plane to speed up the process of extracting vector profiles.

3 Results

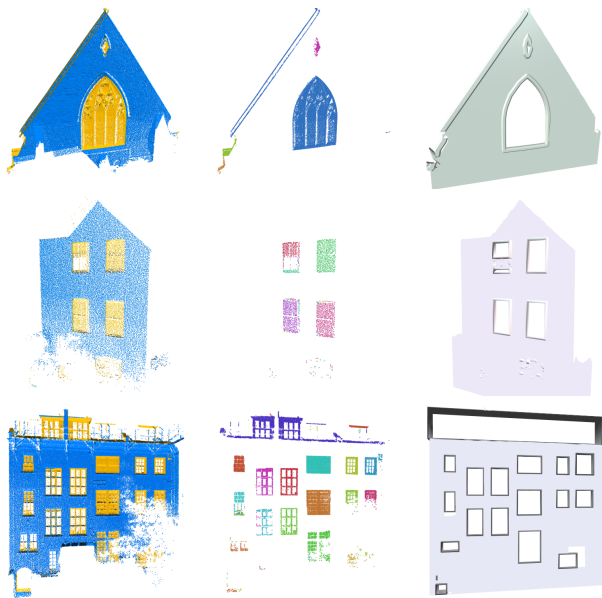This section presents early qualitative results of the algorithm.

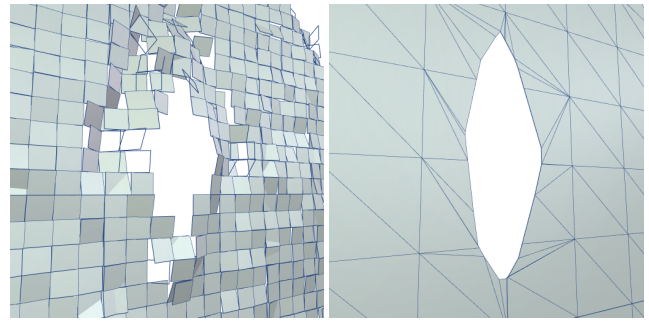**Figure 4:** *Facades segmented and reconstructed by the algorithm*

Figure 5: *Comparing the topology of volumetric reconstruction using the regular arrangement of planes (left) to the algorithm (right)*

3.1 Further Research

In terms of the future, there are still vital problems to address to enhance the performance and utility of this reconstruction operator. This final section outlines some of the key further challenges.

Surface-Element Reconstruction - boils down to automatically resolving procedural split logics in order to enable data-driven modelling of segmented window clusters using sets of generalised cylinders. Figure 6 illustrates a formal representation suitable for this.
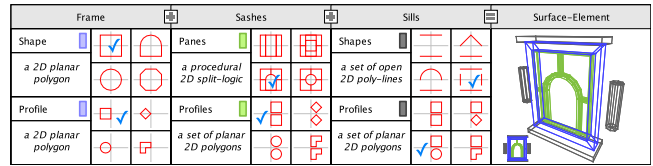

Figure 6: *an abstract formal representation of a window - suitable for data-driven reconstruction and model-based template fitting*

Non-Planar and Curved-Facades present tricky cases for the operator. This is largely due to the sensitivity of the binary-split. This is because it requires a precise wall-representation which is more expensive to recover and manipulate in the case of curved facades.

Multi-Modal Reconstruction: Merging Aerial & Ground Scans would enable the automatic reconstruction (and temporal-update) of complete (mass and surface-detail) *sparse* city-scale models. This is the current focus of continued research - figure 7 illustrates.
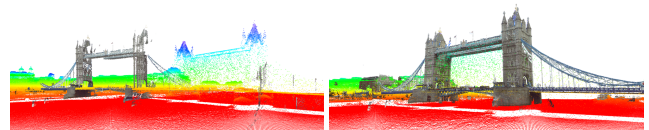

Figure 7: *further investigations - automatically merging multiple sources of laser scan for complete building reconstruction*

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