



REVERSE DESIGN

From Photogrammetric As-Is Survey to HBIM

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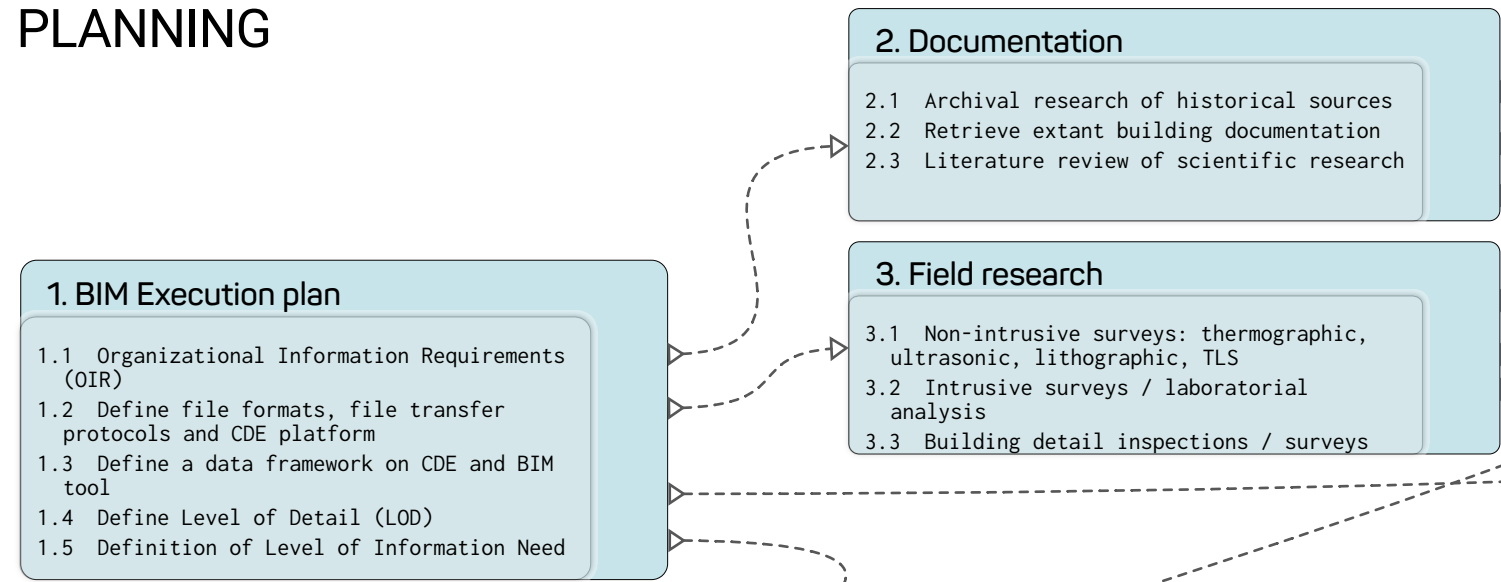
ABSTRACT

Cultural heritage encompasses both the physical and intangible legacies of a society, preserved from the past, safeguarded in the present, and passed on to future generations. It embodies a community's identity, culture, and history, bridging various disciplines such as art, architecture, tourism, sociology, anthropology, geography, and landscape studies. Ensuring broad access to and enjoyment of cultural heritage is a crucial consideration, as it strengthens community identity and fosters a deeper connection to shared history. The concept of Historical Building Information Modeling (HBIM) was introduced more than ten years ago (Murphy et al 2009) to address these criticalities of CH buildings. HBIM has many similarities to As-is BIM modeling in which a model must be reverse designed from as-is survey and create a library of parametric objects considering historical data and onsite information, yet the particularities of CH call for domain specific workflows.

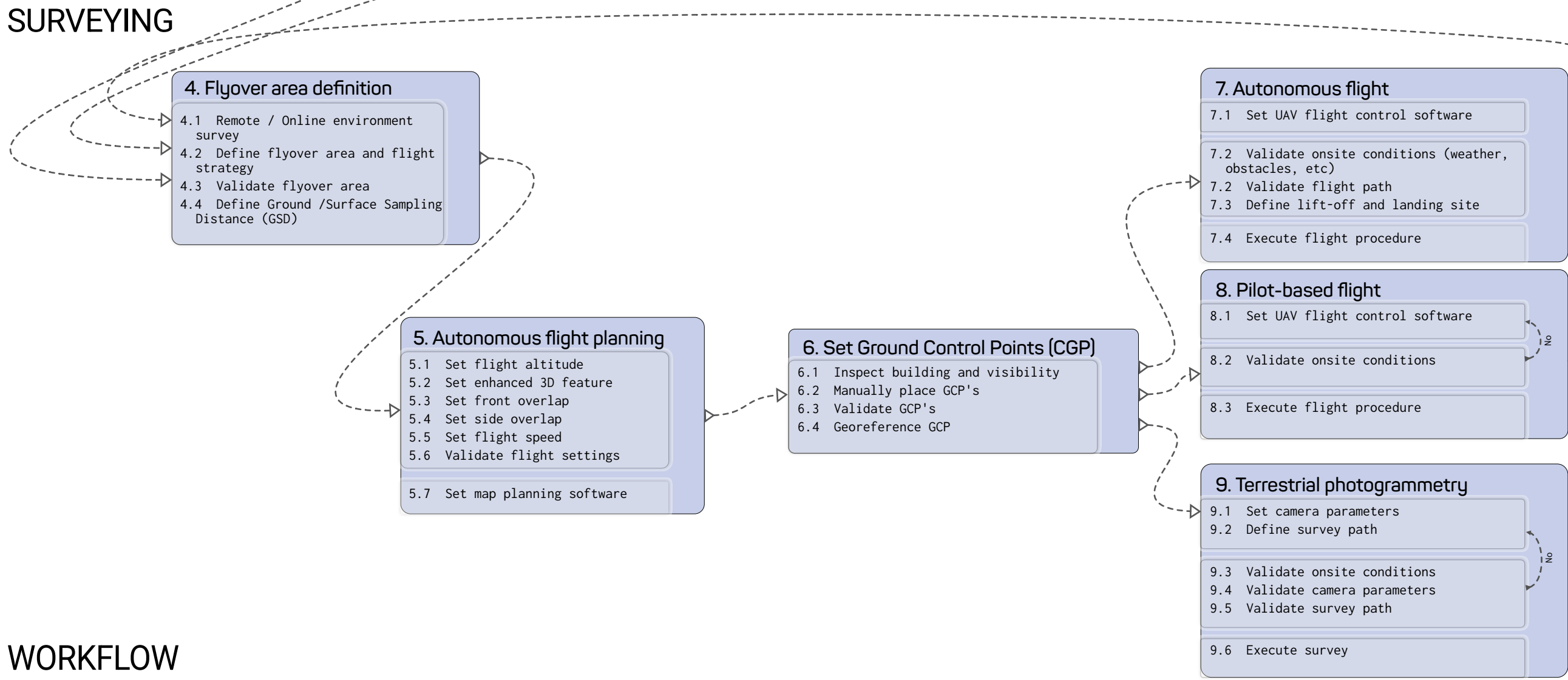
INTRODUCTION

HBIM has been adopted for a variety of purposes across the world, including facilities management and cultural heritage preservation of both tangible and intangible values (Lombardi & Rizzi, 2024). This communication presents a methodology outlining the process of generating Heritage Building Information Models (HBIM) for cultural heritage sites using terrestrial and aerial photogrammetric surveys. The integration of Terrestrial Laser Scanning (TLS) is also considered. The complete workflow comprises the following stages: Planning, Surveying, Reconstruction, Pre-Processing, and BIM Modeling.

PLANNING



SURVEYING

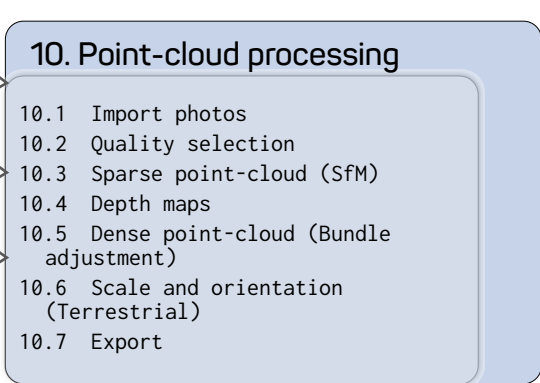


WORKFLOW

The planning stage of the workflow involves making overall decisions about the requirements for data collection and modeling. The **first step** in this stage, the **BIM Execution Plan (BEP)** is to decide the requirements for the HBIM model vis-a-vis the needs and expectations the model is expected to address. As in standard BIM practice, this typically departs from a OIR document to make decisions on what semantic information is to be captured (LoIN) and with which level of geometric detail (LOD), how it is going to be stored and processed. These informations are relevant to define the GSD or SSD of the Surveying stage. The remaining steps of this stage, **Documentation** and **Field Research**, are in effect also survey strategies that can run along the photogrammetric surveys. Nevertheless, gathering existing building documentation can be important to inform the survey stage, particularly on the planning of the interior surveys and on the need of multi-scale survey data collection.

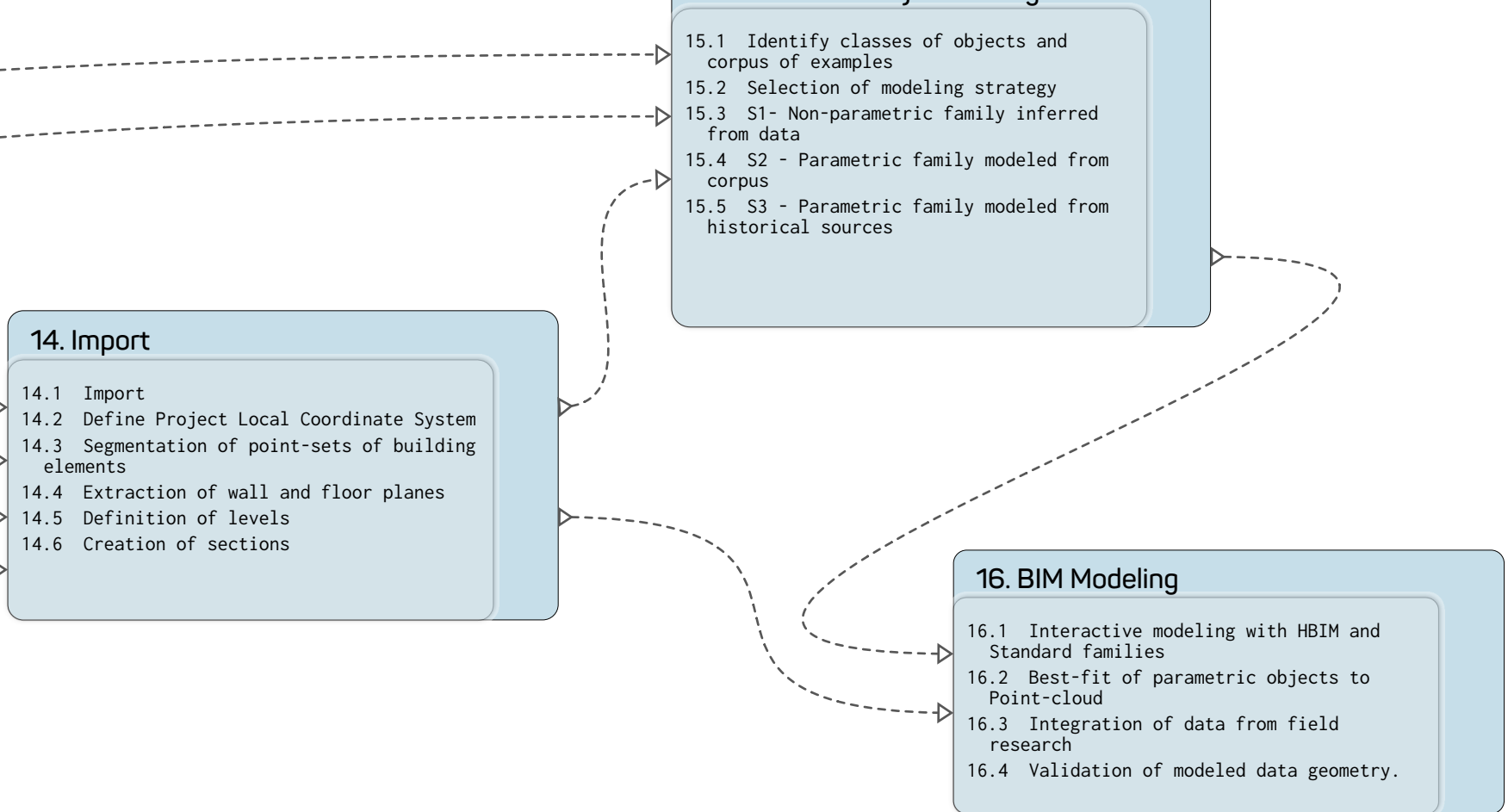
The **surveying phase focuses on the comprehensive collection of data using both terrestrial and aerial methods**. This stage ensures the geometric and semantic accuracy of the resulting HBIM model. Integration of multi-scale multi-process surveys is assured by adequate preliminary geo-referencing and by setting ground-control points. All photosets are oriented in photogrammetric software. Sparse point clouds are generated through Structure-from-Motion (SfM) techniques, followed by the creation of dense point clouds using depth maps and bundle adjustment methods. These point clouds are then scaled and oriented to match real-world coordinates, enabling seamless integration with GIS and CAD systems. A **pre-processing stage** for all pointsets, including clipping, decimation and segmentation follows. An optional alignment step can be pursued if point-sets are not properly scaled, aligned or referenced.

RECONSTRUCTION

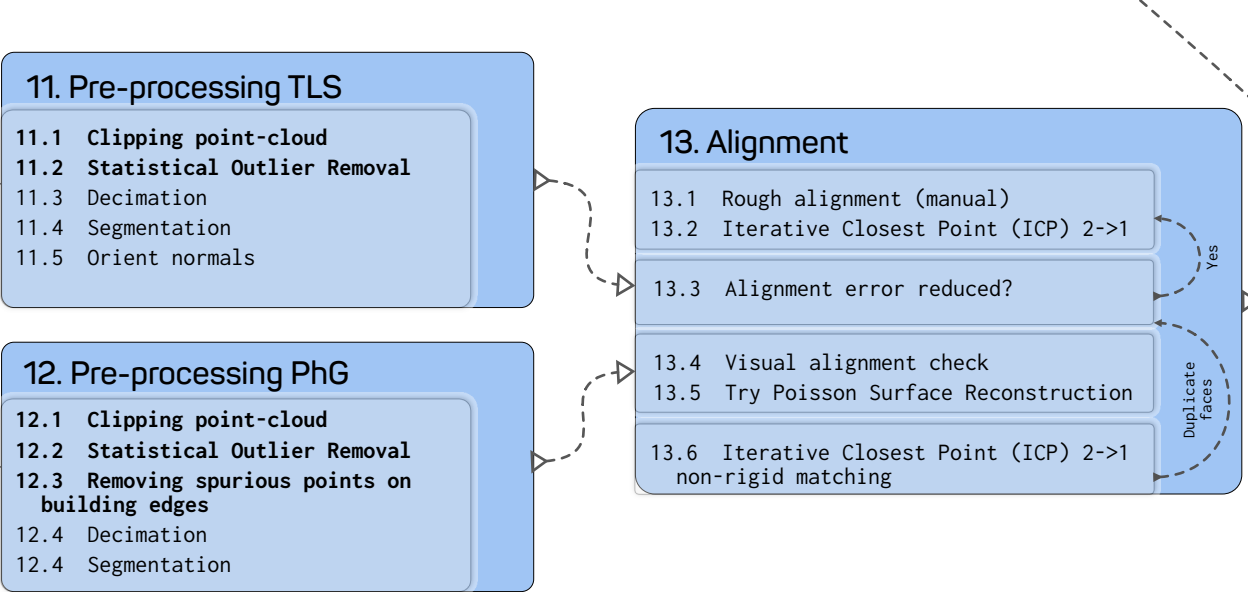


The **alignment process** begins with rough manual adjustments, followed by Iterative Closest Point (ICP) algorithms for precision. Non-rigid matching techniques, such as Poisson Surface Reconstruction, are applied when necessary to address inconsistencies. Visual checks and error reduction are conducted to validate the alignment. The **last stage BIM Modeling** is aimed at **integrating the information from disparate sources**. A critical step is to create objects families for interactive modeling. This may be achieved using one of three strategies: creating 3d models from point data, create a parametric object family from a corpus of examples, model object types from historical sources. Interactive modeling tools are used to ensure that parametric objects align with the point-cloud data. Data from field research, such as material properties and structural details, are integrated into the HBIM model. Validation of the modeled geometry is conducted to ensure accuracy and consistency with historical and survey data.

3D/ BIM MODELING



PRE-PROCESSING / ALIGNMENT



CONCLUSION

This communication proposes a systematic approach to generating HBIM models for cultural heritage sites, integrating photogrammetry, TLS, and BIM technologies. By addressing the unique challenges of CH, this methodology supports the preservation, management, and dissemination of cultural heritage, fostering a deeper understanding and appreciation of historical assets for future generations. This approach is software agnostic and may be developed using open-source software.

Figure 1. Example of one of the strategies for object family creation from point-cloud data extraction. A) Profile is extracted from sections to the point-cloud. Revolution axis is the best fit line for horizontal sections centerpoints. B) A solid object is composed from a revolution NURBS surface and primitive objects. C) Family is created using BIM authoring tool and semantic data is filed in the object properties table.

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