HYBRID DIGITAL TWIN: LEVERAGING 3D MODELING AND STRUCTURED DATA FOR PHOTOVOLTAIC SYSTEM AUTONOMY

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Introduction

This work highlights the significant aspects of developing a digital twin (DT) for photovoltaic (PV) systems, with a focus on digital models that enable the safe and efficient use of autonomous platforms (unmanned aerial and ground systems. The integration of autonomous systems introduces the need for a different approach to modelling principles to enhance navigation coordination and real-time image transfer.

Methodology

As part of ongoing research, this study implemented a hybrid Digital Twin of a solar farm using 3D modelling and database implementation. We present findings from the terrestrial laser scanner (TLS), structure-from-motion (SfM) 3D models, and interaction with the database structure for an experimental PV farm. The aim is to investigate the comparative involvement of applying any of the techniques for utility-scale PV farms.

Leica RTC360, a type 1 3D laser scanner with an integrated HDR spherical imaging and visual inertial system, was used for the TLS 3D model following IEC 60825-1:2014. DJI Mavic 3 Thermal Drone with RTK module and Emlid Reach RS2+ as a base for RTK was used for the SfM model.

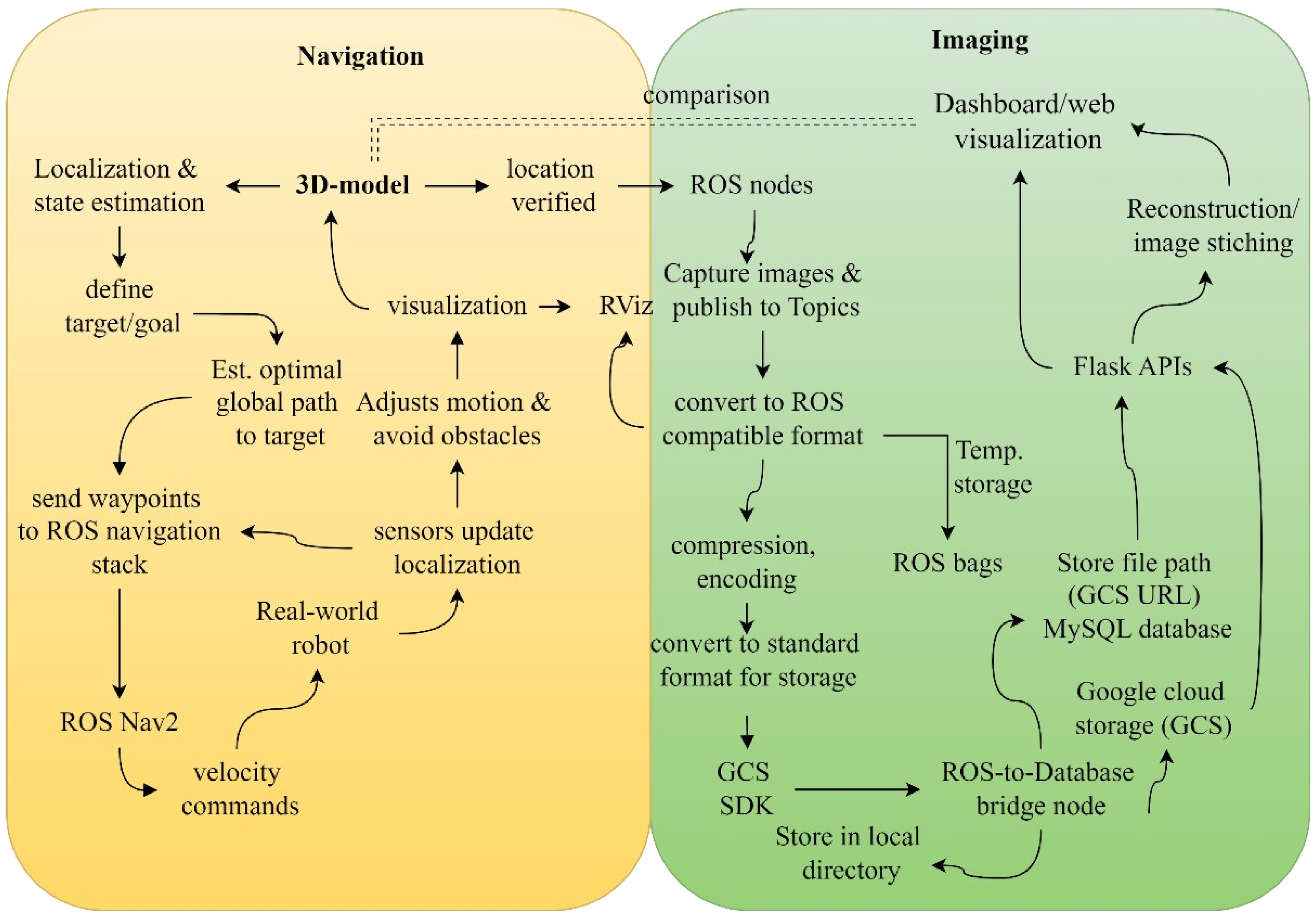


Fig. 1. HDT process flow

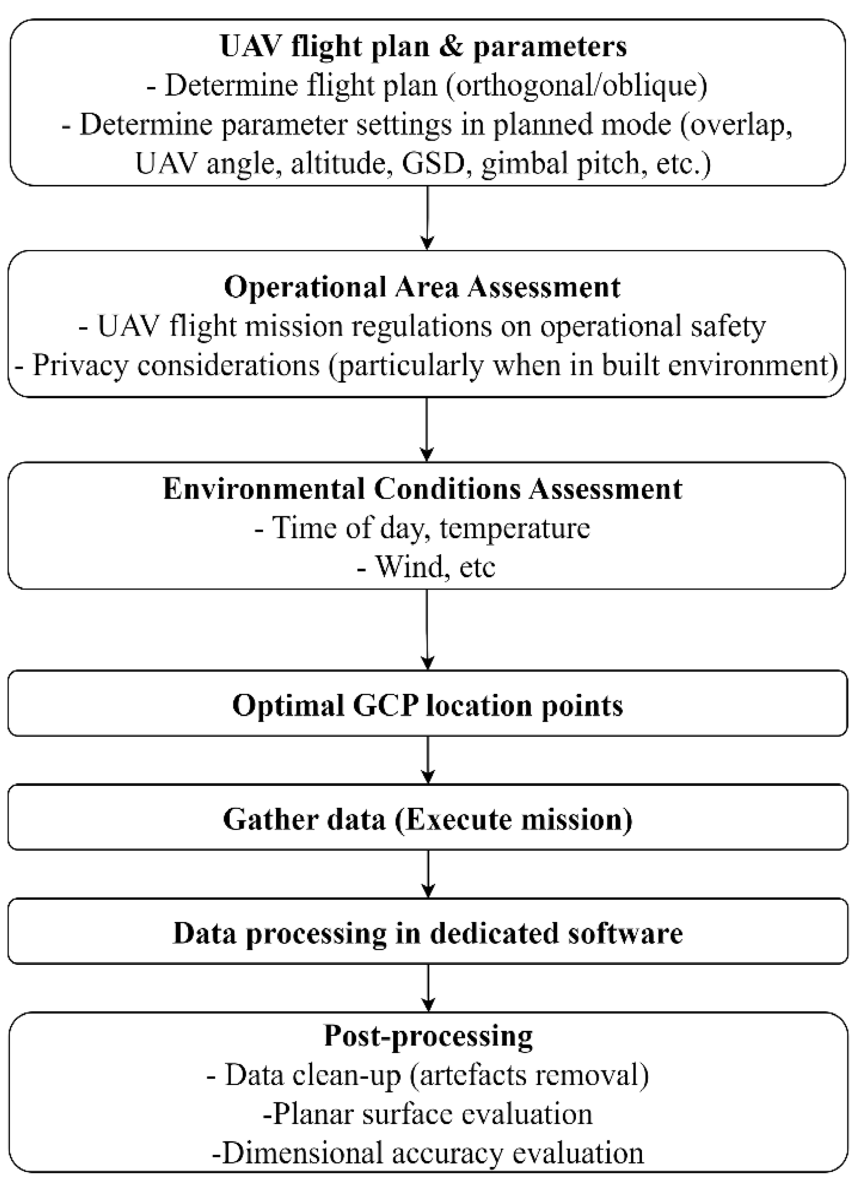


Fig. 2. SfM process flow

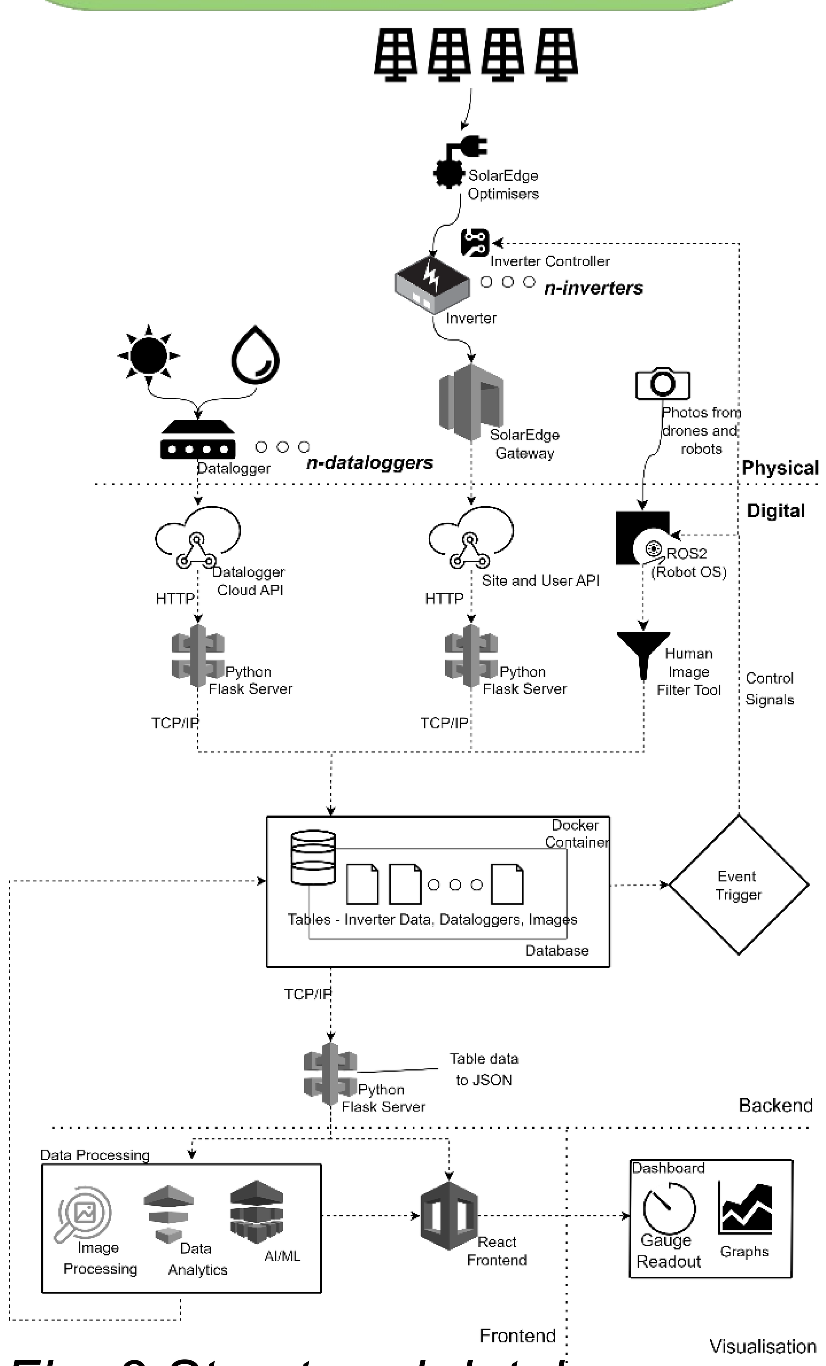
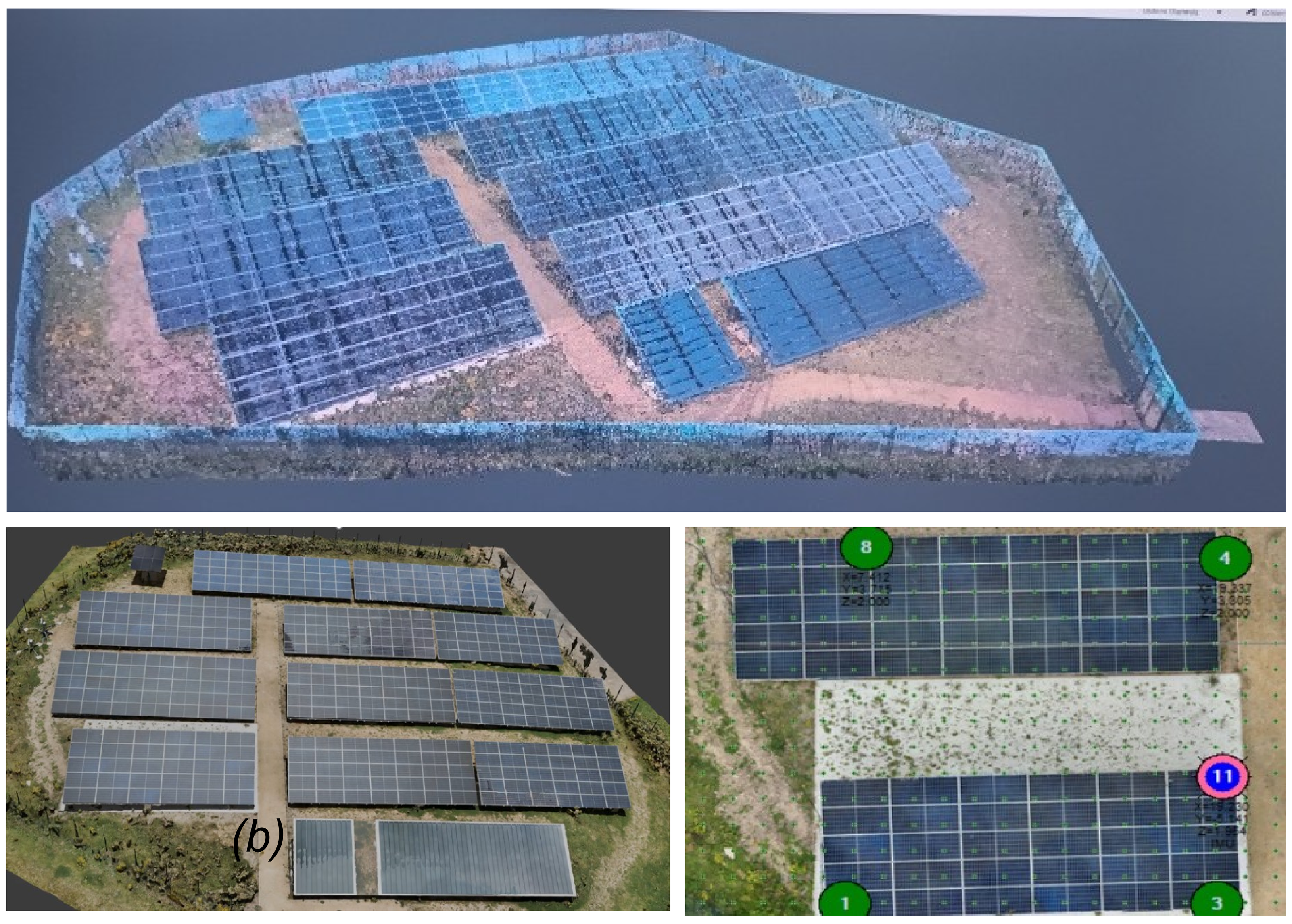


Fig. 3 Structured database

Fig. 1 describes the overall HDT process flow and how the developed models integrate into the DT. The SfM process flow is shown in Fig. 2, while the data-driven integration and processing for all exogenous and PV site data are described in Fig. 3.

Results



(a)

(c)

Fig. 4. Outcome of (a)TLS 3D-model, (b) SfM 3D model, (c) Model verification

Table 1. Dimension verification

Parameter	Length (Meas./Act.) m	Width (Meas./Act.) m	Height (Meas./Act.) m
Array1	13.70/14.11	5.67/5.74	2.42/2.63
Array 2	12.72/12.77	5.27/5.34	2.74/2.98
Array 3	3.07/3.16	3.40/3.47	2.73/3.03
Array 4	12.74/12.77	5.30/5.34	2.80/2.78
Array 5	16.63/16.68	5.03/5.04	3.02/2.72
Est. Ave. Error	0.13	0.05	0.09

In Fig. 4, we show some results, including the outputs of the TLS and SfM models. While the TLS model already provides significant point cloud level precision, the SfM model is prône to inaccuracies; as such, model verification is performed to ascertain the dimensions of some regions of interest (ROI) essential to autonomous navigation.

It is observed that, while the TLS model provides more accurate information for under PV module navigation compared to the SfM, it is a very dense model and requires significant computational resources. As such may become unrealistic for utility-scale farms.

Despite successful implementation of the described model, the observed limitations indicate a potential for more accurate 3D modelling from commercial PV software to use the initially designed model for PV-DT implementation.

Conclusions

This work has successfully implemented 3D models for integration and full-scale development of a PV-DT using a real-time system at the University of York, United Kingdom. It expands on the potentials of DT for PV systems, particularly for use with autonomous systems, which are severely limited in the literature. In addition, the fundamentals apply to several interoperable systems for monitoring and maintenance.