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Blockchain Crop Assurance and Localisation

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***Abstract*—Food supply chain assurance should begin in the field with regular per-plant re-identification and logging. This is challenging due to localisation and storage requirements. A proof-of-concept solution is provided, using an image-based, super-GNSS precision, robotic localisation per-plant re-identification technique with decentralised storage and blockchain technology. ORB descriptors and RANSAC are used to align in-field stones to previously captured stone images for localisation. Blockchain smart contracts act as a data broker for repeated update and retrieval of an image from a distributed file share system. Results suggest that localisation can be achieved to sub 100mm within a time window of 18 seconds. The implementation is open source and available at: https://github.com/garry-clawson/Blockchain-Crop-Assurance-and-Localisation**

I. Introduction

Food fraud increased 46% between 2016 to 2019 [1] and a further 20% in 2020 [2]. With increased participation and longer supply chains, the annual global trade of counterfeit food and drink is currently measured between $6.2 billion USD and $40 billion USD [3]. Food fraud can occur when false claims are made about processes performed on food, or when food is physically substituted for low quality items [4].

The farm is the the first stage of an assured supply chain. Farmers may assure their crop by proving that the plants they sell are the same plants that have been grown over time according to systems which have been monitored and recorded. To do this, they need to show regular records of each plant over its whole growth cycle, such that each neighbouring pair of records over time is similar enough to demonstrate the identity of the same plant, and such that the growth of the plant over the records is consistent with the claimed systems. For example, application of non-organic fertilizers would give rise to growth spurts which could be recognised as such.

A key prerequisite for on-farm crop assurance is the ability to re-identify and record specific and individual plants within a crop over time. Open source swarm robots [5] are now low-cost and could be used to drive and monitor a crop daily. However current civilian GNSS does not provide per-plant accuracy, being typically limited to around 50-200mm . In countries which lack trusted central authorities for data logging – which are often those where food fraud is an issue – it is important to be able to store and retrieve the plant data, using accessible, decentralised and non-propriety technology. Here, we investigate a novel proof-of-concept pipeline utilising image alignment techniques, blockchain smart contracts and decentralised storage to provide sub GNSS localisation within an in-field environment.

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II. Methodology

A. Data Collection

Image data is collected by photographing at set furrow points directly adjacent to individual seeded plants at 90^0 overhead. This is achieved with a Arducam 5MP Mini Camera Module integrating a CMOS OV5642 image sensor mounted aboard an open source agri-robot [5]. A *template* image, taken at seeding, and a *current* image are used to perform the image alignment phase of the pipeline. As a proof-of-concept, a ground stone measuring 110mm long by 80mm wide is used for image alignment and throughout the localisation pipeline.

B. Image Alignment

Image alignment requires two images. A *template* image, taken at seeding adjacent to the seed itself, and a *current* image taken when the agri-robot is within $\pm$200mm for location and 10° orientation, the accuracy of the robot's GNSS and IMU. Oriented FAST and Rotated BRIEF (ORB) feature detection [6] are used to provide image registration. Random Sample Consensus (RANSAC) [7] is used for image alignment.

C. Image Storage and Retrieval

Image storage is implemented using the Interplanetary File System (IPFS) [8]. Images are uploaded and retrieved via the Infura API [9]. The IPFS organises a users data into cryptographic hashed objects using a Distributed Hash Table (DHT) that are connected by their content identifiers (CIDs) [10]. A CID is automatically returned to a user when data has been added to the IPFS.

D. Image Notarisation

The public Ethereum blockchain is used to store IPFS CIDs and act as a notarisation agent. The Web3.py [11] library is used to interact with Ethereum, calling a smart contract developed in Solidity [12]. The smart contract holds a list data structure which is appended with the CID when the smart contract is called through an associated transaction. Notarisation effectively takes place when the block that holds the transaction is mined. Ganache [11] is used to create a localised Ethereum blockchain and Truffle [11], a testing framework and asset pipeline for blockchains using the Ethereum Virtual Machine (EVM), is used to deploy the required image storage and migration contracts to the blockchain.

III. Results and Discussion

Image retrieval, alignment, notarisation and storage was repeated 50 times and recorded. Stage one measured the average time to retrieve a template stone image from IPFS. Stage two,

(a) (b)

Fig. 1: Stage 2 of localisation pipeline: (a) Successful alignment of a 45° inclined and and 90° rotated current ground stone image, to its template image taken 2 days apart. (b) Successful image alignment of several smaller stones taken at a 45° inclined angle to its template image, taken 2 days apart.

aligned a current image to its template as shown in Fig. 1. Stage three uploaded a current image to IPFS upon successful alignment. Stage four updated the ImageStore contract with the returned IPFS CID. Each stage was completed independently and timed using the Python *Time* library. Average file size uploaded to IPFS was 918kB. Ping rate of the network used was 59 ms with an upload bandwidth of 285 Mbps and 10.5 Mbps down. Gas costs to instantiate the ImageStore contract was 288327 Gwei or 0.52USD. To append a CID hash to the ImageStore list contract was 92186 Gwei, equivalent to 0.17USD using June 2022 Gwei to USD ETH prices. Cycle time summary statistics for stages 1-4 are shown in Table I.

TABLE I: Cycle times for each pipeline stage (measured in seconds)

Stage	Description	Min	Max	Avg
1	Retrieve Image from IPFS	9.4	13.7	10.3
2	Align Image to Template	3.9	5.8	4.6
3	Upload Image to IPFS & get CID	16.3	18.7	17.3
4	Add IPFS CID to Blockchain	2.5	4.3	3.1

A total cycle time of 18 seconds for the pipeline process was seen, with stages 1, 2, and 4 completed in series, and stage 3 being performed in parallel during the next iteration of seed imaging. To retrieve an image and complete alignment averaged 14.9 seconds. Assuming seed drilling every 30cm for a crop of turnips, a 1 acre field ($63m^2$) would require 11,907 template images taking 59 hours to notarise. On the next pass when localising, a total of 49 hours would be required to cover the full crop using one robot. Ideally, the system would be able to perform image retrieval, alignment, storage and notarisation in real time. Using the open source swarm agri-robot with a straight-line velocity of 0.39m/s, total seeding time would take approximately 22 minutes for a similar size field. Connecting to the cloud based IPFS node via the Infura API was the main cause for the majority of the delay. Hosting a local IPFS node could significantly reduce this process time. Appending a CID to the smart contract averaged 3.1 seconds. The global Ethereum network requires 14 seconds for this notarisation operation. Batching of transactions to occur at the end of field rows could resolve this bottleneck. Inspection of the image alignment overlays showed that *current* to *template* image offset was 7%-15% as demonstrated in Fig. 1. Measurements were taken at the 0^0, 90^0, 180^0 and 270^0 position around a main feature stone. This equates to an average 10-15 mm alignment accuracy across the sample stones. This suggests that image alignment could be used to perform localisation to sub-GNSS accuracy when image translation and rotation is provided to the robot after completion of image alignment.

IV. Summary and Future Work

A proof-of-concept system utilising an in-field open source swarm agri-robot to achieve per-plant re-identification using blockchain smart contracts for notarisation was presented. By using images of natural field stones and aligning them against a previously taken image during seeding, the results suggest that it is possible to achieve higher precision localisation than GNSS, as required for per-plant re-identification, when given an initial approximate GNSS location. Utilising blockchain smart contracts provided a fully transparent and auditable layer enabling on-farm crop assurance without the need for central authorities as intermediaries. This has the potential to reduce food fraud by applying traceability from the seed stage.

Further work improving image alignment pipeline accuracy, data compression, and automation and optimisation of the smart contract would enable broader applicability to a real world environment by reducing overall pipeline cycle times and cost. In our work using image alignment for localisation and blockchain as a notarisation and orchestration agent, our aim is to contribute a proof-of-concept system towards open source and decentralised food supply chain assurance.

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