Introduction
Digital imaging techniques, using non-destructive and predominantly portable investigation tools, are important for research and conservation documentation and aid in recording the condition, informing the treatment, and expanding the understanding of cultural heritage materials. Reflective infrared (IR) imaging has been a routine investigation technique for paper and painting conservation. However, very few studies include the technique for routine documentation of objects including archaeological, ethnographic, historic, sculptural, decorative, and contemporary arts. Visible-induced IR luminescence (VIL) is a newer IR imaging application for object documentation and specific material characterisation. Three-dimensional (3D) imaging techniques, including photogrammetry and white light scanning, can document the shape, dimensions, and volume of 3D objects. The integration of 3D and IR imaging techniques, building on the ability of infrared radiation to penetrate through some pigment and material layers, will offer a new level of documentation of an object's condition, materials, and manufacture.

Conservation and research applications of IR imaging, in the near-infrared (NIR) region between 750–1100 nm (Fig. 1), and 3D imaging are being assessed for object documentation as a preliminary investigation of the feasibility and application of IR photogrammetry.

Research Questions (RQ)
1. What information about materials and manufacture can be provided by documenting objects with IR imaging techniques?
2. How can the setups and workflows for reflected IR digital photography, VIL, photogrammetry, and white light imaging be optimized for accessibility (cost and ease of use) and efficiency?
3. What is the benefit of IR image data in 3D over 2D, assessing the feasibility and applicability of IR photogrammetry?
4. Aside from IR photogrammetry, are there other methods of integrating spectral and 3D imaging data?

Intended Outcomes
- Evidence through increased understanding of materials and manufacture that IR imaging enhances the context and understanding of heritage objects for conservators, curators, and researchers (RQ 1)
- Observations and adjustments for the optimization of imaging setups and workflows from case studies (RQ 2)
- Justifications and examples to support that IR 3D imaging is feasible and applicable as a conservation and research documentation method (RQ 3)
- Preliminary investigation of IR texture mapping onto 3D scanned data as a comparative technique for IR photogrammetry (RQ 4)

Methods

Reflected IR Digital Photography
records the reflection, transmission, and absorption of infrared radiation within the NIR region (Fig. 2b). This technique aids in revealing underdrawings, detecting changes in composition, visualising faded or obscured text, and differentiating and characterising material.

- Camera: Modified Canon 5D Mark II with Coastal Optics 60 mm macro lens with Peca 906 (87A) IR bandpass filter (Fig. 3)
- Lighting: 2 Lowel VLP Pro-light tungsten halogen lamps
- Software: Adobe Lightroom 5 and Photoshop CS6

Visible-Induced IR Luminescence (VIL)
records the luminescence of a material in the NIR region when illuminated with visible light (Fig. 2c). This technique is specifically used for characterising and differentiating materials particularly Egyptian blue, Han blue, Han purple, and cadmium pigments.

- Camera: Modified Canon 5D Mark II with Coastal Optics 60 mm macro lens with Peca 906 (87A) IR bandpass filter (Fig. 3)
- Lighting: Compact fluorescent lamp
- Software: Adobe Lightroom 5 and Photoshop CS6

White Light Scanning
records the deformation pattern of varying projected light patterns on the object’s surface (Fig. 3). It
- Scanner: Breukmann smartSCAN (Fig. 6)
- Software: Breukmann OptoCAT 2014

Photogrammetry
records the surface geometry of an object by processing digital photographs taken from different views and positions (Fig. 4).

• Camera: Canon 5D Mark II with Coastal Optics 60 mm macro lens
• Lighting: 2 Lowel VLP Pro-light tungsten halogen lamps
• Software: Agisoft Photoscan Pro

Photographing & Analysis

- Photographs taken from different views and positions (Fig. 4)
- Software: Agisoft Photoscan Pro

Case Studies

- Study Case 1: Using IR digital photography, VIL, photogrammetry, and white light scanning to document 10 objects with different materials and combination of materials at two institutions (RQ 1 & 2)
- Study Case 2: Training & Research using techniques and software to explore the integration of image data including texturing mapping, the use of photographs to provide colour information on 3D models (RQ 4)
- Visualisation & Analysis using image data to investigate the application of IR imaging for object documentation and the feasibility of IR photogrammetry (RQ 1 & 3)

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Literature

Fig. 1. The electromagnetic spectrum indicating the NIR region used for techniques like reflected infrared digital photography and VIL.

Fig. 2. (a) Visible light image, (b) NIR image, and (c) VIL image of a mango wood vase purchased for this research to test imaging techniques. Egyptian blue details were painted onto the vase to research VIL setup and acquisition.

Fig. 3. Modified digital camera and bandpass filters. The modification includes removing the IR cut-filter and colour filter array. The camera is sensitive to NIR radiation and the filters are used to restrict the spectral range of the camera.

Fig. 4. Screenshot from Agisoft Photoscan, a photogrammetry processing software, indicating the camera positions from the image acquisition.

Fig. 5. The various light projection patterns from a white light scanner on a mango wood vase.