AI for Heritage Conservation: Automating Structural Health Inspection and Reporting of Monuments

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India's monuments are living records of our history. From rock shelters, stupas, temples, forts, palaces, and bridges to excavated sites, they are repositories of knowledge from our past for future generations. Preserving them is both our cultural duty and a scientific challenge.

The Archaeological Survey of India (ASI), set up in 1861 under the Ministry of Culture, manages thousands of protected monuments, including several UNESCO World Heritage Sites. As these structures face weather, pollution, urban activity, and natural disasters, we need methods that are adaptable, consistent, and timely to assess their structural health and to ensure their prompt restoration and proper upkeep.

Research in our lab addresses these challenges by developing AI-enabled visual inspection and reporting pipelines tailored to heritage contexts. We train deep learning models, including Convolutional Neural Networks and Vision Transformers, to detect, segment, and localise damage in high-resolution images. A core thrust of our work is building robust, domain-specific datasets. We collect field imagery using handheld RGB cameras and UAVs of brick and stone masonry from ASI or state-protected monument sites and annotate damage categories at the pixel level. Fig. 1 shows images from Shaniwar Wada, Pune, an ASI Grade-A protected monument, along with our manually annotated dataset of damaged brick masonry.

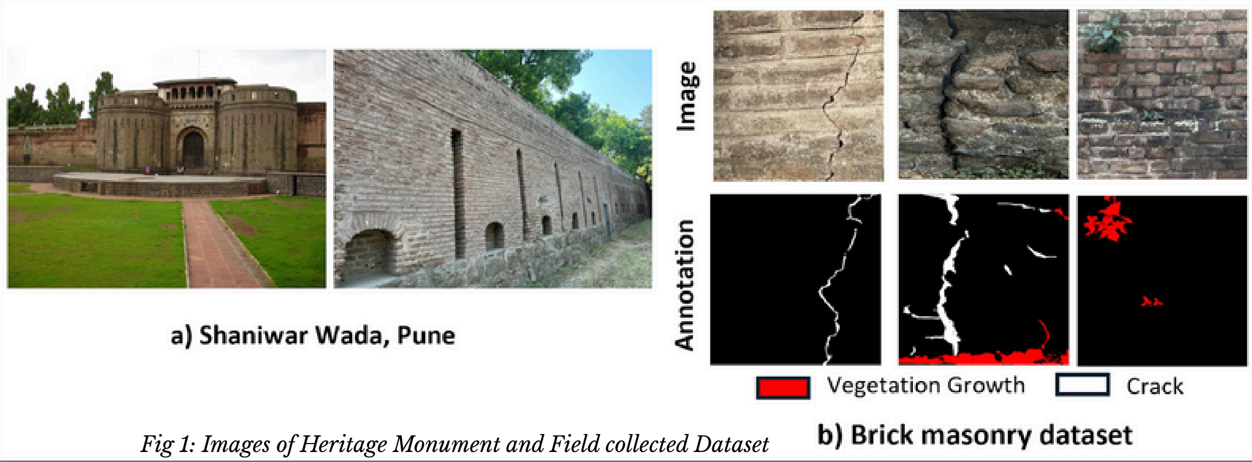

Fig 1: Images of Heritage Monument and Field collected Dataset

Today, manual inspection remains the norm. Teams rely on visual walkthroughs, scaffolding, and limited-access surveys to identify defects such as cracks, vegetation growth, stains, surface loss, material delamination, and biological growth on heritage building materials. This process is labour-intensive, subjective, risky on tall or complex monuments, and slow to turn observations into actionable conservation plans and reports. For large complexes or inaccessible façades, coverage gaps are common, and repeat assessments are difficult to standardise when carried out by various teams across time.

This dataset is then augmented with curated Indian and global datasets to improve generalisation across materials, textures, lighting, and weathering patterns.

On the algorithm side, we use advanced training strategies—specialised loss functions for class imbalance, augmentation for viewpoint and illumination changes, and modern computer vision architectures—for precise pixel-wise segmentation of defects on heritage monuments.

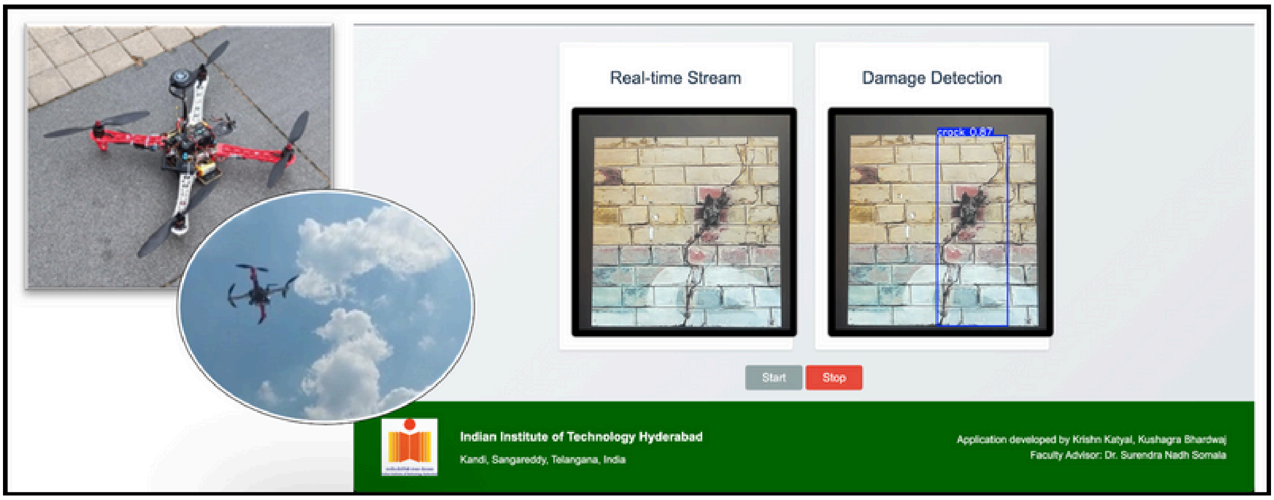

Fig 2. : UAV platform for structural health inspection and the custom web app for real-time data acquisition and inspection.

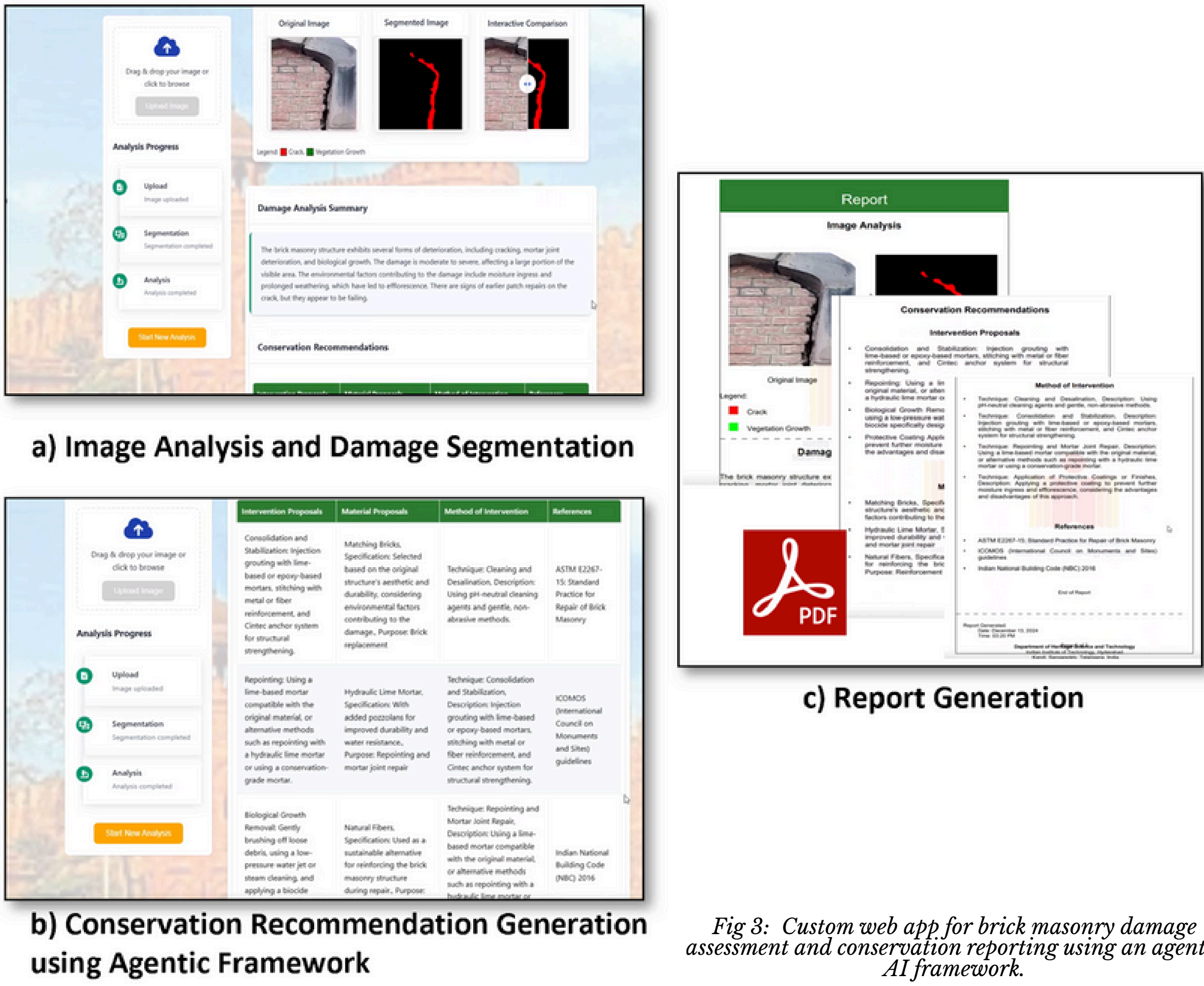

Fig 3: Custom web app for brick masonry damage assessment and conservation reporting using an agentic AI framework.

To support on-site data collection and decision-making, we have also built a custom web application that streams live video from UAVs for real-time assessment. Lightweight object detection models provide immediate damage localisation on the live feed, creating a base for adding more specialised, fine-tuned models. Our hardware stack includes a custom, low-cost quadcopter for live inspections and a commercial drone for wider data capture—together offering flexible, field-ready coverage for real-time inspection and monitoring, with significantly reduced risk to personnel. Fig. 2 shows the UAV platform for structural health inspection and the custom web app for real-time data acquisition and inspection.

Beyond detection, we translate analysis into AI-assisted conservation reporting. A vision–language module interprets images and their segmentation masks to assign damage severity levels. An agentic AI layer orchestrates multiple large language models to generate conservation recommendations by proposing restoration interventions, identifying compatible repair materials, and outlining the methodology to be adopted for restoration, by retrieving this information from vetted sources such as ICOMOS charters, CPWD guidelines, ASI manuals on Indian heritage materials, and peer-reviewed literature. The system then compiles structured reports to support condition documentation and the preparation of tender technical specifications for the rehabilitation and restoration of our monuments.

Figure 3 shows the custom web app for brick masonry damage assessment and conservation reporting using an agentic AI framework.

In essence, AI can drive a step change in heritage monument conservation by making inspections faster, safer, and more consistent, while speeding up documentation and reporting for timely action. This, in turn, helps architects and public stakeholders expedite contracting and start restoration sooner. Crucially, our approach keeps human experts at the centre—AI augments rather than replaces conservation judgement. As these tools mature, stakeholders can prioritise resources, track changes over time with both qualitative and quantitative metrics, and plan interventions that are timely, minimally invasive, and materially compatible. The end goal of our research is to establish a reliable system—built on highly optimised computer vision models and an agentic AI framework—that is thoroughly tested and validated for heritage contexts. The fusion of AI with heritage science will not only safeguard monuments for future generations but also strengthen institutional capacity to preserve India's tangible heritage.

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