Tirtha

An Automated Platform to Crowdsource Images and Create 3D Models of Heritage Sites

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SAN SEBASTIAN - SPAIN

Introduction

- ***Cultural Heritage*** (CH) comprises tangible and intangible elements, reflecting diverse cultural values. Tangible Cultural Heritage (TCH) often houses Intangible Cultural Heritage (ICH). CH acts as a looking glass into our ancestors' beliefs and way of life.
- With rapid socioeconomic growth, CH sites are coming under threat from natural as well as anthropogenic sources.
- UNESCO's 2015 policy[1] aims to help member states preserve & harness CH sites for sustainable development, but ***resource constraints*** limit documentation efforts.
- For example, UNESCO recognizes only 42 sites in India as World Heritage sites, while the Archaeological Survey of India (ASI) considers about 3,695 as Monuments of National Importance. Including State Protected Monuments, the count increases *by* 4,506.
- ***These counts exclude several sites, yet to be recognized***, that hold significance to various communities. This issue is prevalent in many developing countries.
- To address this, we draw on the concepts of ***Digital Heritage*** and ***Crowdsourcing*** to present a cost-effective method to document CH sites, in culturally rich but resource-limited countries like India.

[1] https://whc.unesco.org/document/139747

Introduction

- ***Digital Heritage*** **(DH)** uses digital technologies to record and disseminate knowledge from CH sites, e.g., by creating 3D models of those sites and providing access to them over the internet → ***3D documentation***.
- ***Crowdsourcing***, a portmanteau of “crowd” and “outsourcing’, involves obtaining information and services from large groups of people à la Wikipedia[1], Zooniverse[2] or OpenStreetMap[3].
- Inspired by these concepts and related works, we present ***Tirtha*** **- an end-to-end automated web platform for crowdsourcing images of CH sites and creating their 3D models**. The word “Tirtha” is Sanskrit for "a place of pilgrimage", and is commonly used to refer to the sacred sites of Hinduism.
- By leveraging the proliferation of smartphones, advancements in smartphone photography and web technologies, Tirtha aims to overcome the cost and accessibility challenges in CH documentation.
- We aim to:
  - democratize digital documentation by expanding the audience to non-experts, such as tourists or locals.
  - provide a dataset of crowdsourced images and 3D reconstructions for research in computer vision, heritage conservation, and related domains.
  - build a community of experts and non-experts.

[1] https://www.wikipedia.org/ [2] https://www.zooniverse.org/ [3] https://www.openstreetmap.org

Pillars of Tirtha

1. ***Crowdsourcing / Participatory DH***: The platform should have an intuitive web interface for crowdsourcing images from the general public and experts alike, while also displaying 3D models, aiding in site discoverability.
2. ***Cross-Referenceability***: The platform should archive individual reconstructions, assign persistent identifiers for easy referencing, and offer an API for research use.
3. ***Free and Open-Source Software (FOSS)***: The platform should be FOSS, built entirely on FOSS technologies, cultivating a community and ensuring sustainability.
4. ***End-to-end (E2E) Automation***: The platform should require minimal input, making it user-friendly and adaptable to resource-constrained settings.

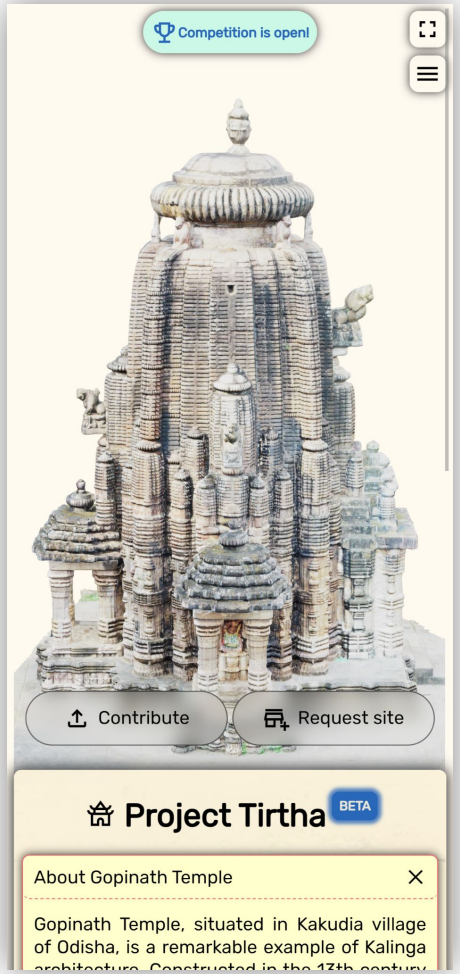
Tirtha is designed to fulfill all of these specifications.

Comparison with existing platforms

Platforms	Crowdsourced	CrossRef	FOSS	E2E Automated	Active
PhotoCity [*Tuite et al 2011*]	●	○	○	●	○
3D-ICONS [D'Andrea et al. 2012]	○	●	○	○	○
HeritageTogether [Miles et al. 2014]	●	○	○	●	○
MicroPasts [Bevan et al. 2014]	●	○	●	○	●
Rekrei [Vincent et al. 2015]	●	○	●	○	●
SOCH [Dhonju et al. 2018]	●	○	○	○	○
Aioli [Pamart et al. 2020]	○	○	○	●	○
CrowdHeritage [Kaldeli et al. 2021]	●	●	○	○	●
Tirtha (This work)	●	●	●	●	●

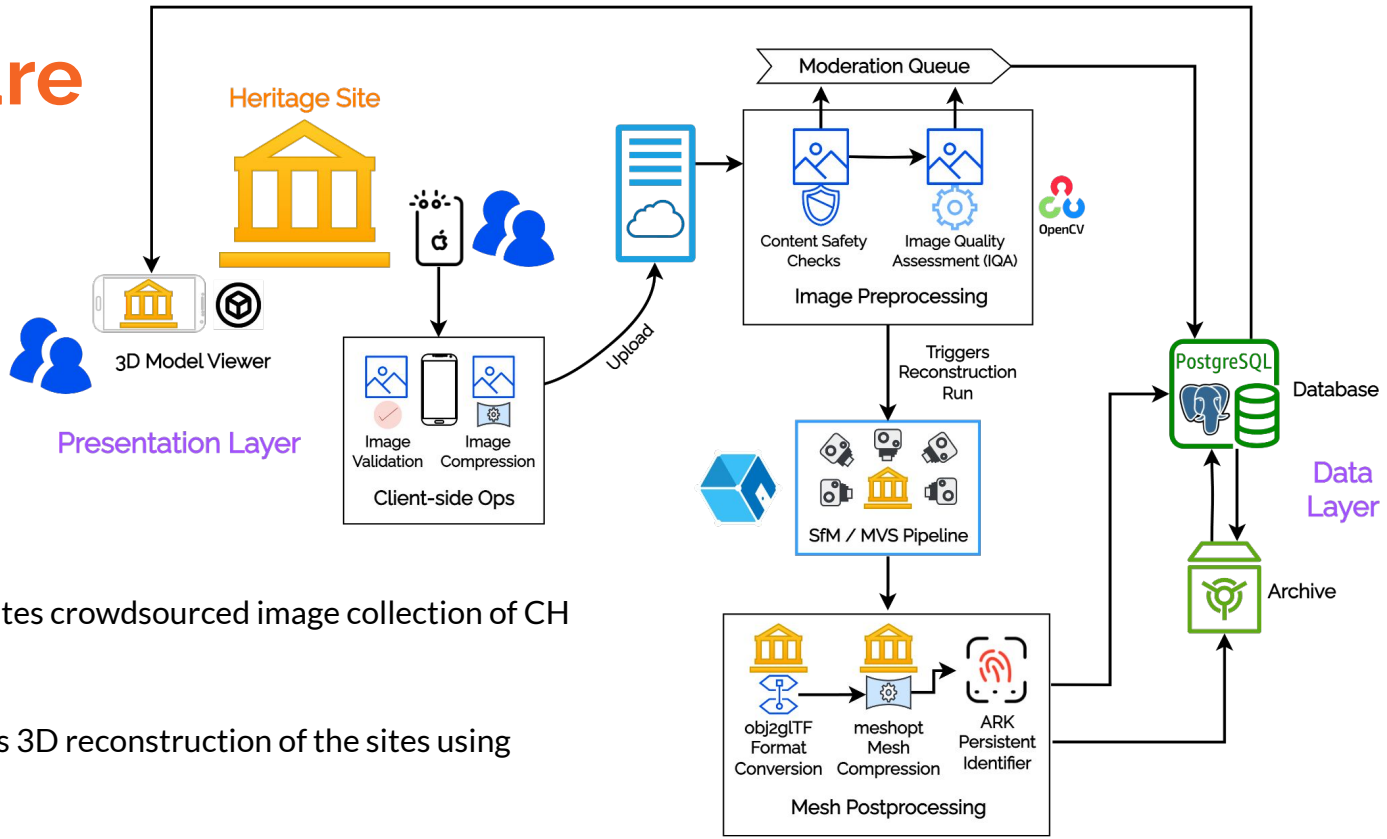
Project Tirtha

- Tirtha (https://tirtha.niser.ac.in) is an ***end-to-end automated*** web-based crowdsourcing platform.
- It ***democratizes*** heritage documentation by enabling anyone to contribute images of CH sites, which eases the resource constraints of heritage organizations. The images are used in a photogrammetry pipeline to create 3D models of the sites.
- The models and images, both with metadata, are stored as datasets under non-commercial Creative Commons licenses, facilitating further use in research and creative disciplines. People can view & download 3D models of heritage sites on the web platform itself.
- The database is searchable and ***cross-referenceable*** with persistent ARK[1] identifiers, making it a useful resource for heritage documentation, education, and especially research. All contributors are credited in the model metadata.
- It is completely ***FOSS*** and the source code is available at https://github.com/smlab-niser/tirtha-public.



[1] https://arks.org/

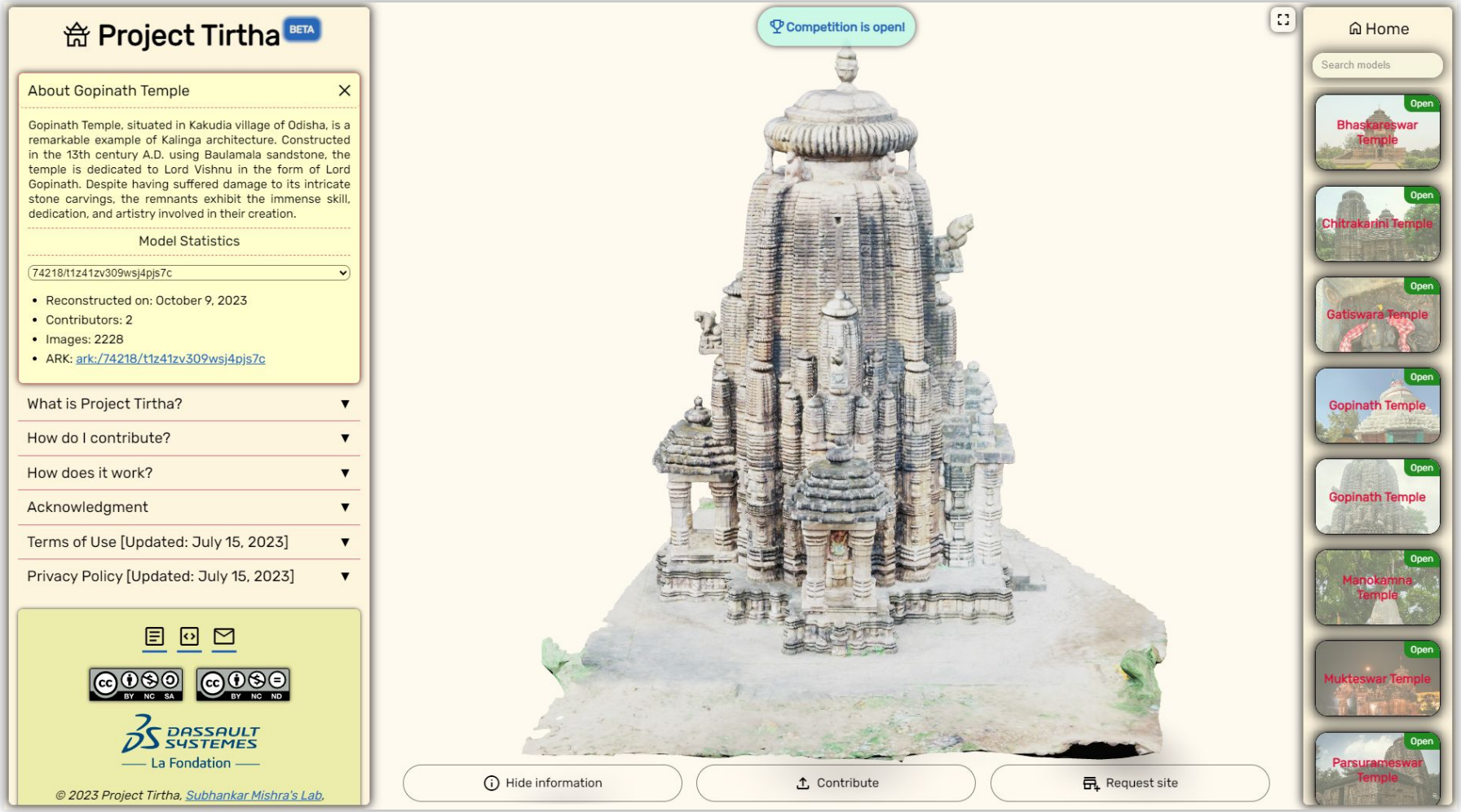
Architecture



- **Presentation Layer** facilitates crowdsourced image collection of CH sites.
- **Application Layer** manages 3D reconstruction of the sites using photogrammetry.
- **Data Layer** manages storage of the collected images, generated 3D models & associated information.

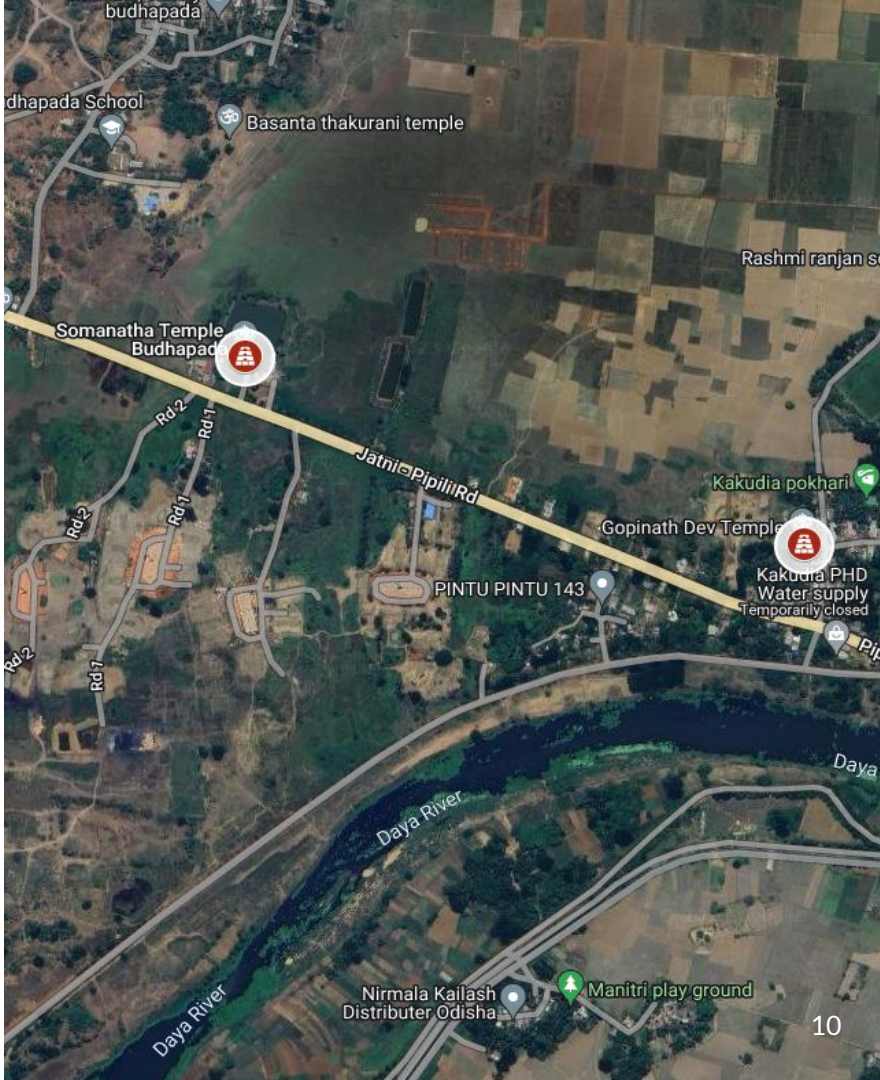
Select notes on the architecture

- Login is not required to view or download the 3D models. It is only required to contribute images.
- The image validation and compression steps are fully client-side, in order to reduce bandwidth usage.
- An image enhancement step can be added to the image preprocessing step in the Application Layer, that denoises, deblurs and color-corrects images for better downstream reconstruction results.
- For the SfM / MVS step, we wrap over AliceVision Meshroom binaries to create a custom photogrammetry pipeline. This is done to have access to the variety of utilities offered by Meshroom, while also limiting the scope of the pipeline to relevant features.
- The final step in the process is the creation of a persistent Archival Resource Key or ARK identifier. This is done for each new reconstruction run for each CH site, after new contributions come in. It enables cross-referenceability for each of the reconstruction runs. Each ARK entry in the database also stores all the metadata about the site in JSON format.
- Tirtha is currently deployed on-premise in a Docker container on a Ubuntu 22.04 LTS server, with 24 vCPUs, 512 GB RAM, 4 TB storage (with 80TB archive storage), and 1 A100 GPU. Celery & RabbitMQ are used to automate & scale the web application, written in Django.
- Given Tirtha's modular design, setting it up on cloud platforms like Amazon Web Services (AWS) should be straightforward.


Project Tirtha
BETA
About Gopinath Temple
Gopinath Temple, situated in Kakudia village of Odisha, is a remarkable example of Kalinga architecture. Constructed in the 13th century A.D. using Baulamala sandstone, the temple is dedicated to Lord Vishnu in the form of Lord Gopinath. Despite having suffered damage to its intricate stone carvings, the remnants exhibit the immense skill, dedication, and artistry involved in their creation.
Model Statistics
74218/t1z41zv309wsj4pjs7c
Reconstructed on: October 9, 2023
Contributors: 2
Images: 2228
ARK: ark:/74218/t1z41zv309wsj4pjs7c
What is Project Tirtha?
How do I contribute?
How does it work?
Acknowledgment
Terms of Use [Updated: July 15, 2023]
Privacy Policy [Updated: July 15, 2023]
DASSAULT SYSTEMES
La Fondation
© 2023 Project Tirtha, Subhankar Mishra's Lab,
Competition is open!
Hide information
Contribute
Request site
Home
Search models
Open
Bhaskareswar Temple
Open
Chitrakarini Temple
Open
Gatiswara Temple
Open
Gopinath Temple
Open
Gopinath Temple
Open
Manokamna Temple
Open
Mukteswar Temple
Open
Parsurameswar Temple

Results

- We conducted pilot studies on two State Protected Monuments located in the Khurdha district of Odisha, India.
  - ***Somanatha temple,*** dedicated to Lord Shiva
  - ***Gopinatha temple***, a Vaishnav monument
- Some features of the monuments:
  - Construction period: 13th century AD
  - Building material: Baulamala sandstone
  - Architectural style: Kalinga architecture, with *intricate* carvings & floral motifs
  - Condition: Some damage due to age & vandalism
- We have two sets of datasets for both sites: ***expert-sourced*** & ***crowdsourced***. The former was collected using drone-mapping and the latter, using smartphone cameras.
- We also have benchmark 3D models for these sites, created using expert-sourced data via a proprietary software called *Agisoft Metashape*.



Results

Crowdsourced
(Smartphones)

Expert-sourced
(Drones)

Results

Crowdsourced (Smartphones)

CH Site	SfM Registered Views	Mesh Compression
Somanatha Temple	250 / 251	261 → 56 MB (≈78.5%)
Gopinatha Temple	267 / 268	442 → 90 MB (≈79.6%)

Expert-sourced (Drones)

CH Site	SfM Registered Views	Mesh Compression
Somanatha Temple	1513 / 1513	1667 → 326 MB (≈80.4%)
Gopinatha Temple	1956 / 1956	1331 → 197 MB (≈85.2%)

Somanatha Reconstruction

Tirtha on Expert-sourced data

Expert-sourced mesh

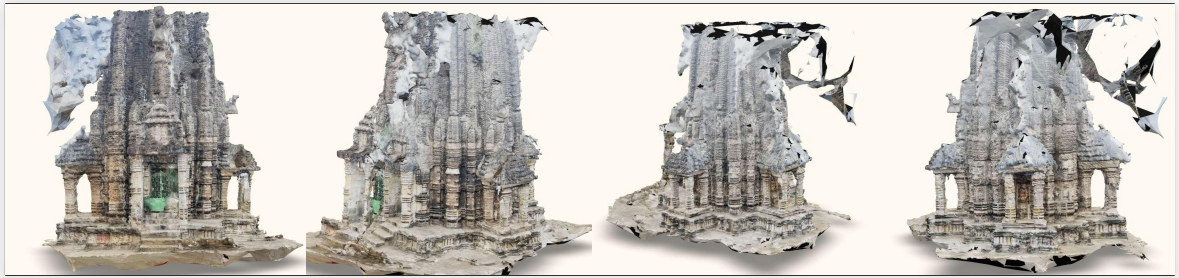
Tirtha on Crowdsourced data

Gopinatha Reconstruction

Tirtha on Expert-sourced data

Expert-sourced mesh

Tirtha on Crowdsourced data



Close-up Comparison

Tirtha on Crowdsourced data

Tirtha on Expert-sourced data

Image Quality Assessment

Somanatha Temple

Gopinatha Temple

Image Quality Assessment

Failed IQA

Passed IQA

Limitations

- Quantifying the quality of the data and corresponding 3D reconstructions, especially for downstream research use, remains a concern.
    - The quality of the 3D models depends heavily on the quality of crowdsourced data.
    - For most sites, higher resolution scans are not feasible or available. As such, there is no ground truth to assess reconstruction accuracy.
    - Note that even low-quality reconstructions serve the purpose of conserving the memory of the site and facilitating its study, even if they lack metric accuracy or completeness.
- Crowdsourcing remains an ongoing challenge in terms of volunteer incentives.
    - So far, we have successfully crowdsourced images for only a few sites due to factors like limited awareness about the platform, lack of interest in listed sites, or restricted access.
    - Collaborations with heritage organizations are likely to be beneficial in this regard.
- Another issue is compressing and web-delivery of the meshes, especially on low-spec devices.

Future Work

Tirtha API GIS Data

X3DOM

ARKit / ARCore 3D Tiles

PWA / Native Apps

Texture inpainting

NeRF / Neural representations

Platform development

Native Apps / Guides

Gamification

SIte Signage Forums

Platform Localization

Crowdsourced Annotations

Crowdsourced Model Validations

Contributor engagement

FOSS Community

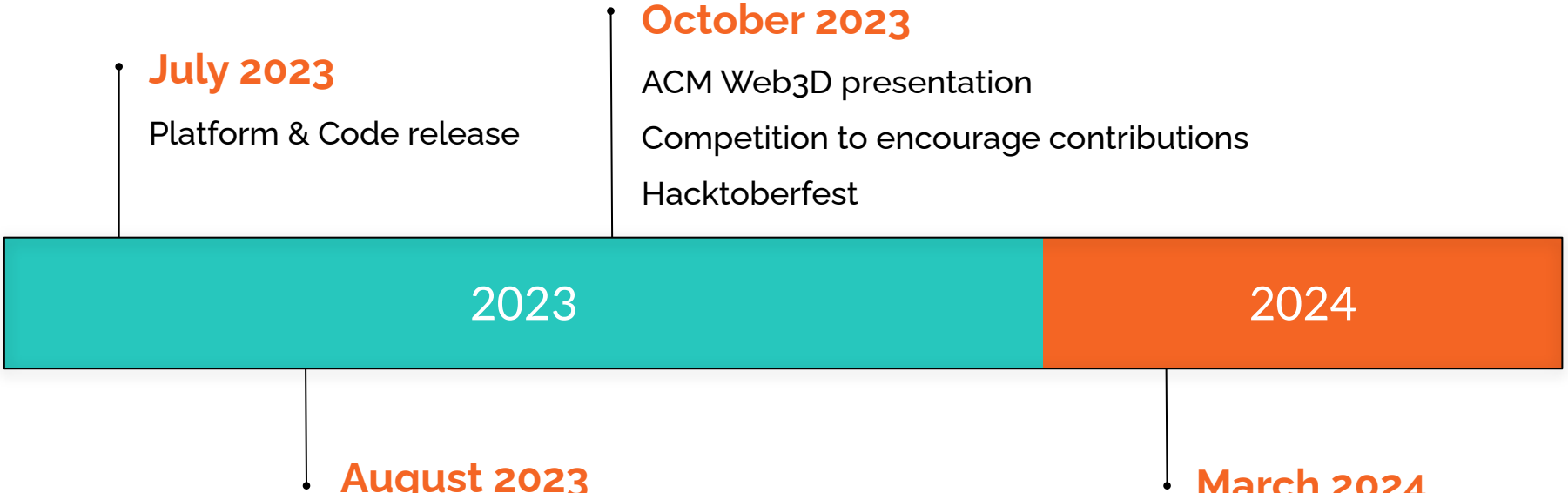
Partnerships with Heritage Organizations

Community Events

Forum for collaboration

Community cultivation

Path ahead


July 2023
Platform & Code release
October 2023
ACM Web3D presentation
Competition to encourage contributions
Hacktoberfest
2023
2024
August 2023
Partnered with Odisha State Archaeology
March 2024
Targeting Google Summer of Code participation

Conclusion

- Advancements in web technologies & smartphone cameras have made crowdsourced image collection a cost-effective way to document cultural heritage sites. Tirtha harnesses these advancements to democratize heritage documentation, while leveraging 3D & web technologies.
- Being FOSS makes it easy for different organizations to deploy and customize Tirtha for different use cases. This can lead to the creation of decentralized repositories for crowdsourced images and 3D models, benefiting scholars and heritage conservation.
- The collected image sets are long-term resources for Computer Vision research & for constructing better 3D models as algorithms improve.
- We envision the data products from Tirtha being used in creative projects, such as extended reality experiences, such as virtual CH site tours, and heritage education.
- We hope to overcome the technical constraints listed before, such as incentivizing contributors, assessing data and reconstruction quality in absence of ground truth & efficiently disseminating 3D models on low-spec devices.
- Overall, Tirtha is a step towards democratizing digital preservation, primarily in resource-limited developing countries. We anticipate Tirtha to have a significant influence on involving local communities in the safeguarding of their invaluable heritage.

Thank you! Questions?

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