



Recover Degrading Artifacts

We are the “History Guardians” !

Claire
Isabella
Luke
Mason



The Team: History Guardians

Luke

I am in 6th grade, and I like to play chess and soccer.

Mason

I am in 5th grade, and I like to do piano and math.

Isabella

I am in 4th grade, and I like art, fencing, and tennis.

Claire

I am in 5th grade and I play lacrosse. And I love animals.



During this season, our team found a specific problem archaeologists face and developed a real solution to help.



SKIT

Claire = Archaeologist

Isabella = Artifact

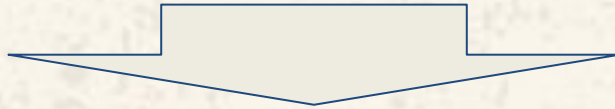
Luke = Narrator

Mason = Inventor

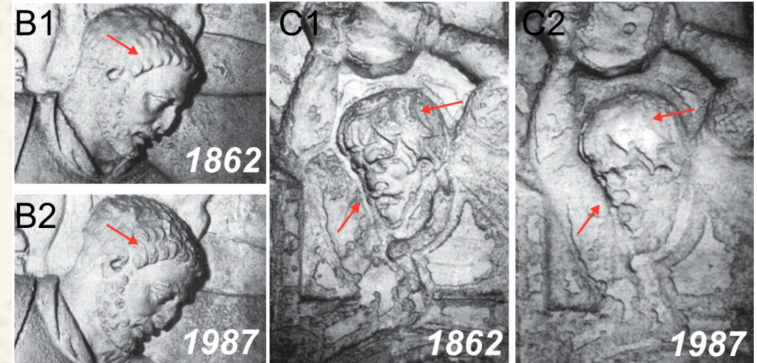


The Problem: Degrading artifacts due to climate change

- **Climate change** is damaging archaeological sites worldwide.^[1]
- Rising temperatures, flooding, erosion, wildfires, ocean chemistry, and melting permafrost are **accelerating the decay of fragile artifacts**.
- **Organic materials** like wood, leather, and textiles are **especially at risk**.



We **lose valuable history** like religious beliefs, rituals, contracts, dates etc. Once the writing degrades, **standard visual tools often can't read it**.



Decay in the Museum of Roman Civilization in Rome

(Source: <https://doi.org/10.3390/heritage7060154>)

References:[1] <https://archaeology.ncdcr.gov/programs/education/climatechange/predictingeffects>



Field Research: The Metropolitan Museum



We visited **the Metropolitan Museum** to see some artifacts from ancient Egypt.
On several stone fragments, words were degraded.





Limitation of Current Technology



- Many traditional digitization tools rely on **clean visual patterns**.
- Damaged artifacts often have stains, distortion, or missing pieces, causing it to be **harder for many current technology to read it**.
- Most advanced imaging systems using either OCR (Optical Character Recognition) or Raman spectroscopy, which are either **not portable or are expensive**, making **on-site analysis difficult**.
- When manual logging is inevitable, inaccuracies and transcription errors occur

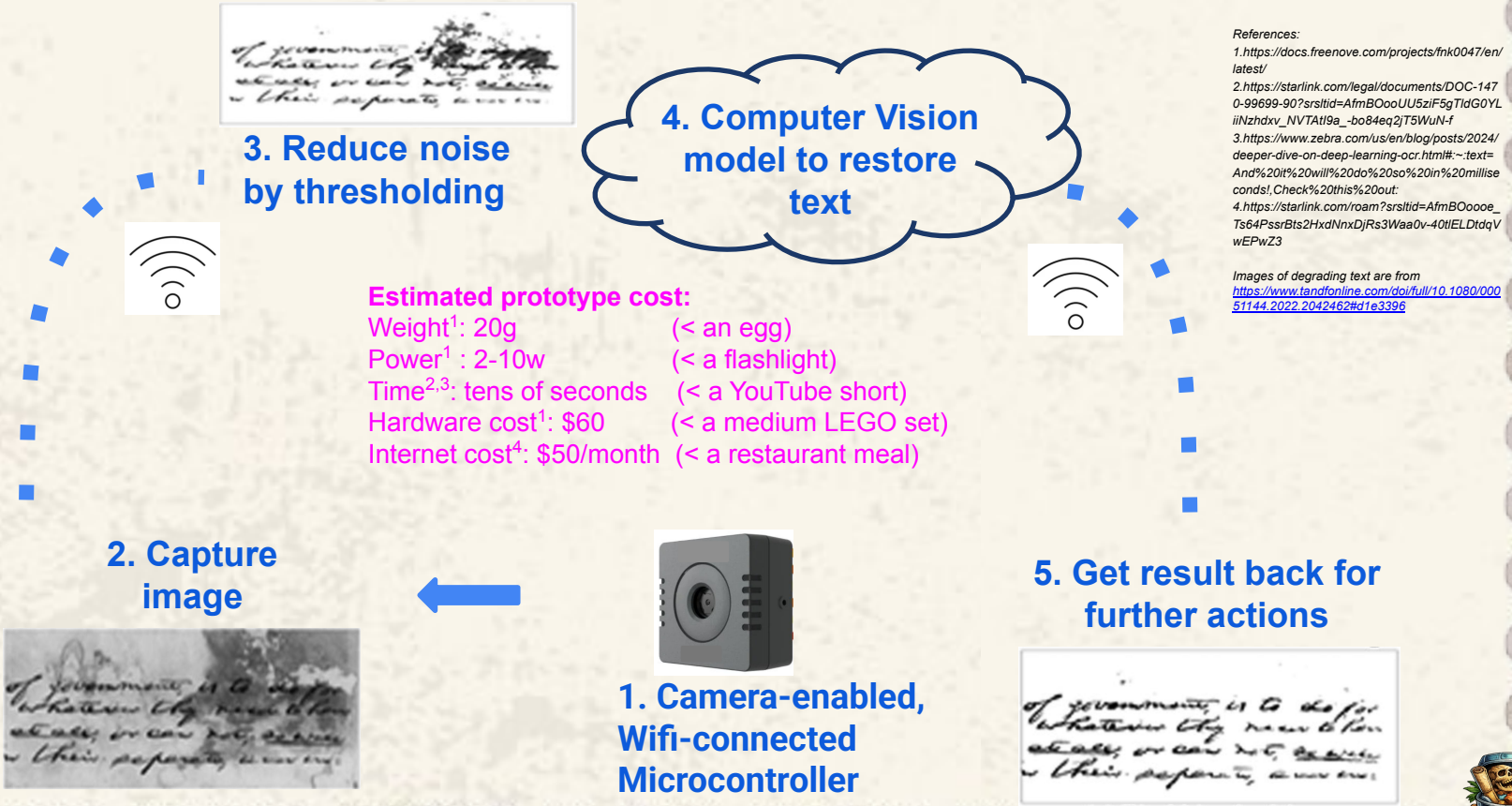


As a result, sometimes important text and symbols are lost or unreadable.

Reference: Sylaiou, S.; Tsifodimou, Z.-E.; Evangelidis, K.; Stamou, A.; Tavantzis, I.; Skondras, A.; Stylianidis, E. Redefining Archaeological Research: Digital Tools, Challenges, and Integration in Advancing Methods. *Appl. Sci.* **2025**, *15*, 2495. <https://doi.org/10.3390/app15052495>



Our Solution: SPARK (Smart Portable Artifact Recovery Kit)



3. Reduce noise by thresholding



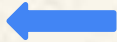
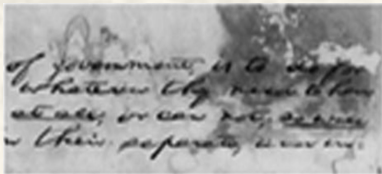
4. Computer Vision model to restore text



Estimated prototype cost:

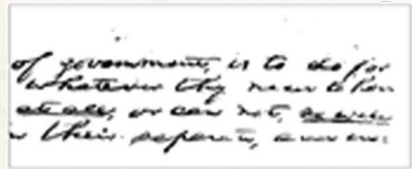
- Weight¹: 20g (< an egg)
- Power¹: 2-10w (< a flashlight)
- Time^{2,3}: tens of seconds (< a YouTube short)
- Hardware cost¹: \$60 (< a medium LEGO set)
- Internet cost⁴: \$50/month (< a restaurant meal)

2. Capture image



1. Camera-enabled, Wifi-connected Microcontroller

5. Get result back for further actions



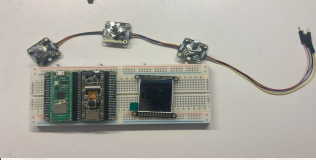

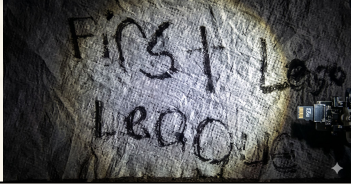
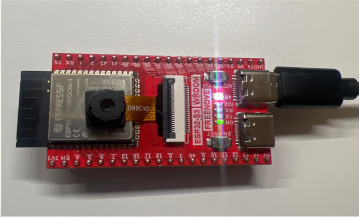

References:

- [1. https://docs.freenove.com/projects/fnk0047/en/latest/](https://docs.freenove.com/projects/fnk0047/en/latest/)
- [2. https://starlink.com/legal/documents/DOC-147-0-99699-90?srsId=AfmBOooUU5zIF5gTldGOYLiiNzhdxv_NVTAtI9a_-bo84eq2JT5WuN-f](https://starlink.com/legal/documents/DOC-147-0-99699-90?srsId=AfmBOooUU5zIF5gTldGOYLiiNzhdxv_NVTAtI9a_-bo84eq2JT5WuN-f)
- [3. https://www.zebra.com/us/en/blog/posts/2024/deeper-dive-on-deep-learning-ocr.html#:~:text=And%20it%20will%20do%20so%20in%20millisecons!,Check%20this%20out:](https://www.zebra.com/us/en/blog/posts/2024/deeper-dive-on-deep-learning-ocr.html#:~:text=And%20it%20will%20do%20so%20in%20millisecons!,Check%20this%20out:)
- [4. https://starlink.com/roam?srsId=AfmBOooouTs64PssrBts2HxdNnxDRjRS3Waa0v-40iELDtdqVwEPwZ3](https://starlink.com/roam?srsId=AfmBOooouTs64PssrBts2HxdNnxDRjRS3Waa0v-40iELDtdqVwEPwZ3)

Images of degrading text are from <https://www.tandfonline.com/doi/full/10.1080/00051144.2022.2042462#d1e3396>



SPARK Iteration Journey from Community Outreach

Who	What They Said	What's the Enhancement	
Family & friends	<i>"Bigger than a phone – phones are more portable."</i>	Moved tuning to the cloud → smaller device which can be mount on a drone	 
Mr. Turner (tech teacher in Rye Country Day School)	<i>"You could move the on-device tuning to cloud and possibly mount it on a drone to reach hard places."</i>		
Mr. John Calvert (tech teacher in Scarsdale Middle School)	<i>"Historical spaces could be dark, maybe attach a LED light to improve image quality"</i>	Added an optional LED light + considered IR/night vision.	
Dr. Shawn Mishra (former engineer at Nix Biosensors)	<i>"When drone goes deep into a cave where there is no satellite signal, you can add a microSD card to save pictures offline"</i>	Added a microSD for storage	 
Dr. Brittany Profit (archaeologist)	<i>"Need offline storage and use feedback to improve models."</i>		



Community Outreach: Expert Interview with Dr. Brittany Profit

- PhD Archaeologist · Excavates at Pompeii & Gabi (Italy)

Q. Why are you an archaeologist?

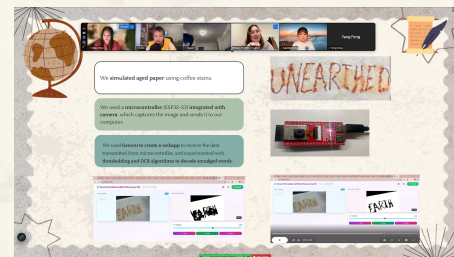
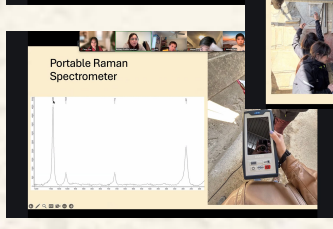
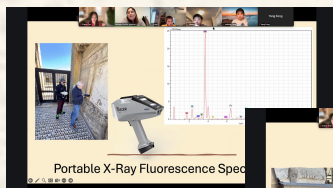
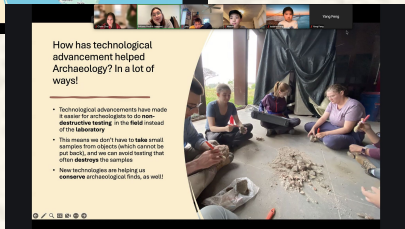
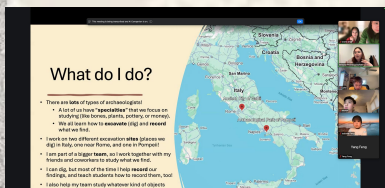
I grew up loving stories of ancient Romans, Aztecs, and Egyptians.

Q. How do you read degraded artifacts?

Portable Raman & XRF (X-Ray Fluorescence) spectrometers complement each other by detecting different elements. Digital microscopes can reveal details in ancient pigments that are not visible to the naked eye, showing examples from Pompeii wall paintings.

Q. What should we add to SPARK?

1. Local storage for offline dig sites – Wi-Fi often isn't there at Pompeii or in caves.
2. Let users correct misreadings – your model gets more accurate over time, and we learn what's actually on the artifact.



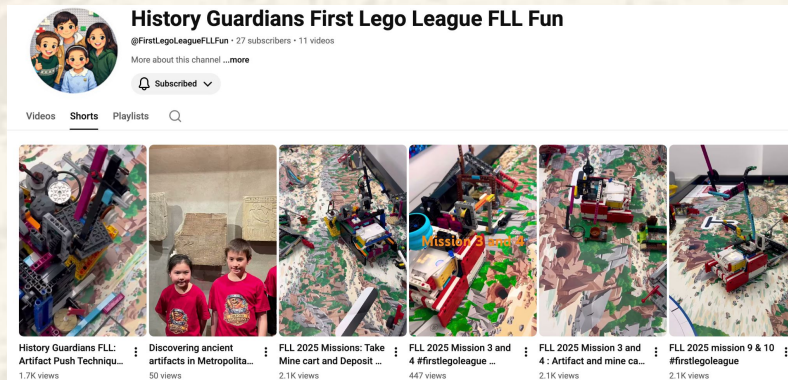
→ *Brittany's feedback further shaped SPARK - offline storage + user feedback to improve the model*



Community Outreach: Youtube Channel and Scarsdale Public Library

Our additional community outreach includes:

- History Guardians FLL Youtube Channel
- Presentation at local public library
 - Share our learnings during the journey of the FLL Unearthed season
 - Get feedback on our innovation project



History Guardians First Lego League FLL Fun
@FirstLegoLeagueFLLFun • 27 subscribers • 11 videos
More about this channel [...more](#)
Subscribed

Videos Shorts Playlists

History Guardians FLL: Artifact Push Techniqu... 1.7K views

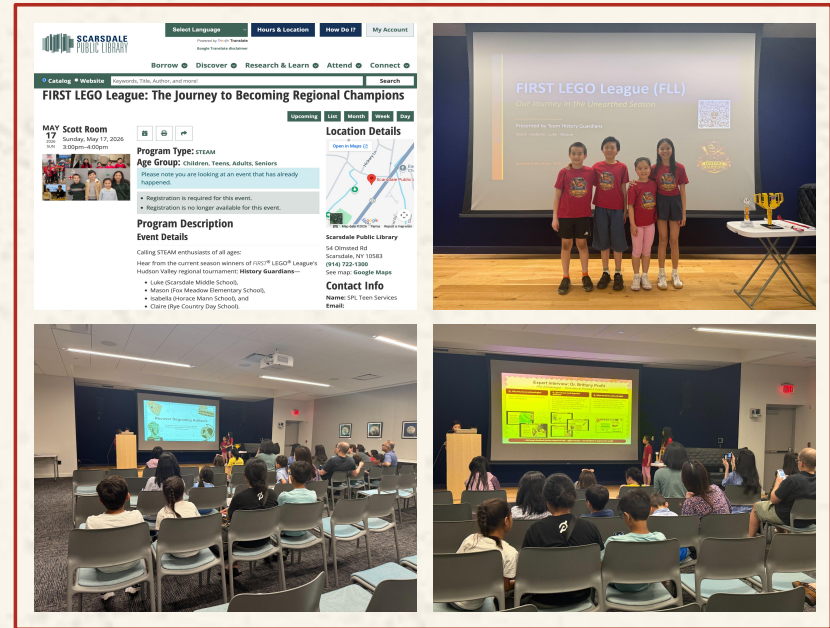
Discovering ancient artifacts in Metropolita... 50 views

FLL 2025 Missions: Take Mine cart and Deposit... 2.1K views

FLL 2025 Mission 3 and 4 #firstlegoleague... 447 views

FLL 2025 Mission 3 and 4: Artifact and mine ca... 2.1K views

FLL 2025 mission 9 & 10 #firstlegoleague 2.1K views



SCARSDALE PUBLIC LIBRARY
Borrow Discover Research & Learn Attend Connect

FIRST LEGO League: The Journey to Becoming Regional Champions

MAY Scott Room
Sunday, May 17, 2026
10:30am-4:00pm

Program Type: on-site
Age Group: children, Teens, Adults, Seniors

Please note you are looking at an event that has already happened.

- Registration is required for this event.
- Registration is no longer available for this event.

Program Description
Event Details

Calling STEAM enthusiasts of all ages:
Hear from the current season winners of 2025 FIRST LEGO League® Hudson Valley regional tournament **History Guardians**:

- Lake Ossawatomie Middle School,
- Mason Elm Middle Elementary School,
- Sabeta Inverse Middle School, and
- Crane Hill Country Day School.

Location Details
Scarsdale Public Library
54 Diamond Rd
Scarsdale, NY 10583
(914) 722-1300
Get more Google Maps

Contact Info
Name: SP: Teen Services
Email:

FIRST LEGO League (FLL)
Get ready for the Unearthed season!

Presented by Teen History Guardians

Scarsdale Public Library

History Guardians FLL: Artifact Push Techniqu... 1.7K views

Discovering ancient artifacts in Metropolita... 50 views

FLL 2025 Missions: Take Mine cart and Deposit... 2.1K views

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FLL 2025 mission 9 & 10 #firstlegoleague 2.1K views

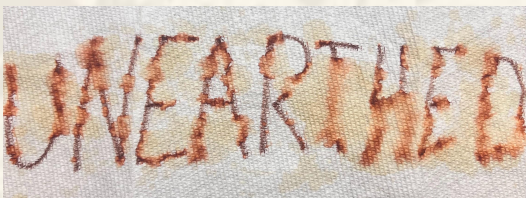


Our Experiment



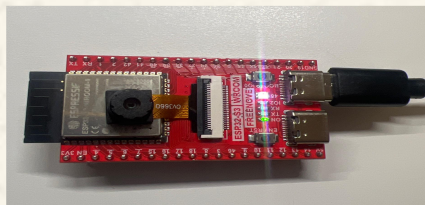
Step 1: Simulate Artifact

We simulated aged paper using coffee stains.



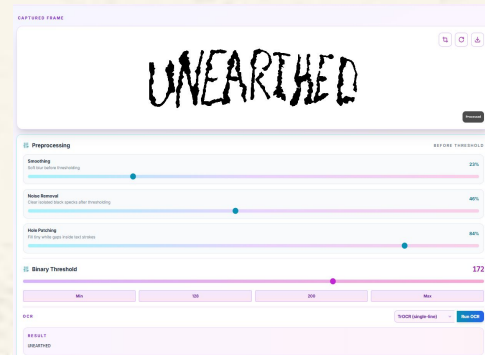
Step 2: Capture the Image

We used a **microcontroller** (ESP32-S3) **integrated with camera**, which captures the image and sends it to our computer.



Step 3: Recover the Word

We used **Gemini** to create a **webapp** [Vision Studio](#) to receive the data transmitted from microcontroller, and experimented with **thresholding** and **OCR** algorithms to decode smudged words.





Further Enhancements



Short-term Improvements

- Reduce the size of the dark-sensor light so it can be mounted on the microcontroller.

Longer-term Improvements

- Instead of using a generic Computer Vision model, finetune a **model specifically for archaeology, and leverage user-guided learning to continuously improve the model.**
 - Understand ancient words/pictures
 - Identify surface damage

Picture	Evolution	Modern character	English
	→	→	sun
	→	→	moon
	→	→	tree
	→	→	mountain
	→	→	water
	→	→	field
	→	→	door

Figure 6.1. The evolution of pictographic characters.



THANK YOU



APPENDIX



Continue to Improve Our Prototype

Four image-preprocessing steps in our Vision Studio webapp to recover damaged text.

1. Thresholding



Initial removal of stains by a brightness threshold

2. Hole Patching



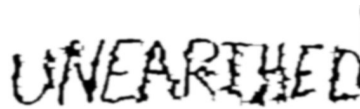
Fill up the missing bits in the letter

3. Noise Removal



Remove the noise so OCR can focus on the letters.

4. Smoothing



Smooth the edges so letters look natural.

Vision Studio — our SPARK webapp

The screenshot shows the Vision Studio webapp interface. At the top, there is a "CAPTURED FRAME" section with a large image of the word "UNEARTHED" and a "Process" button. Below this is a "Preprocessing" section with four sliders: "Smoothing" (23%), "Noise Removal" (46%), "Hole Patching" (84%), and "Binary Threshold" (172). At the bottom, there is an "OCR" section with a "Run OCR" button and a "RESULT" section showing the word "UNEARTHED".



Continue to Improve Our Prototype

We experimented 3 different types of OCR algorithms: Tesseract, TrOCR (multi-line), and TrOCR (single-line).

Tesseract (multi-line)

Best for clean printed documents. Processes entire picture in one go, making it the fastest option.

TrOCR (multi-line)

Best for handwritten or printed text where you want higher accuracy than Tesseract. It reads line by line.

TrOCR (single-line)

Best for distorted handwriting, text, or used for a photo taken at an angle. In our case of detecting simulated ancient artifact, this one performs the best.

OCR ENGINE GUIDE

PIPELINE

Capture - Crop (optional) - Threshold - OCR - Text

Tesseract (multi-line)

HOW IT READS A PAGE

Page image -> Layout analysis -> Lines / words -> LSTM reads sequence -> Text + dictionary cleanup

1. Segment
Find blocks, lines, and character regions from the full page.
2. Decode
LSTM predicts the most likely character sequence across each line.
3. Correct
Language priors help fix likely OCR mistakes in printed text.

What it is: Tesseract is one of the oldest and most widely used OCR engines, originally developed by HP in the 1980s and now maintained by Google. It uses an LSTM (Long Short-Term Memory) neural network — a type of recurrent network designed for sequences — to recognize characters line by line.

How it works: The engine first analyzes the page layout to find text blocks and lines. It then segments each line into words and characters. The LSTM network reads these sequences left-to-right, predicting the most likely character at each position. It uses a built-in language dictionary to correct common mistakes.

Best for: Clean printed documents, receipts, book pages, or any image with clear, high-contrast text across multiple lines. It processes the entire page in one pass, making it the fastest option.

Multi-line - Fast - Full page layout - Struggles with noise - Needs clean contrast

Tip: Use the threshold slider to make text as dark as possible against a white background before running Tesseract. This mimics a "clean photocopy" which Tesseract handles best.

OCR ENGINE GUIDE

PIPELINE

Capture - Crop (optional) - Threshold - OCR - Text

TrOCR (auto multi-line)

TWO-STAGE DIAGRAM

Full page -> Client dark pixels per row -> Line bands -> Crop each band -> Run TrOCR per line -> Join outputs

Stage A: Vision net
Classical projection profiles finds where lines probably are by looking for dense rows of ink.

Stage B: Deep OCR
Each detected line is fed into TrOCR, so the transformer will use a single reading sequence.

What it is: This mode combines classical computer vision with deep learning. It first uses a **horizontal projection profile** to detect where each line of text is, then feeds each line individually to the TrOCR model. You get the accuracy of TrOCR across an entire multi-line image.

How line detection works: The algorithm scans every row of pixels and counts how many are "dark" (ink). Rows with many dark pixels are text; rows with few are gaps between lines. It groups consecutive text rows into bands, sorts them, and crops each band into a separate image. This technique has been used in document analysis since the 1960s.

How it works: Each cropped line image is passed through the TrOCR Vision Transformer encoder - GPT-2 decoder pipeline. Results from all lines are combined top-to-bottom into the final output text.

Best for: Multi-line handwritten or printed text where you want higher accuracy than Tesseract. Ideal for artifact inscriptions, letters, or notes with 2-10 lines.

Multi-line - High accuracy - Auto line detection - Slower option - Needs horizontal text

Tip: The line detector works best when text lines are roughly horizontal. If the image is rotated, crop to straighten it first. Adjust threshold to maximize contrast between text and background — this helps the projection profile find clean line boundaries.

OCR ENGINE GUIDE

PIPELINE

Capture - Crop (optional) - Threshold - OCR - Text

TrOCR (single-line)

MODEL DIAGRAM

Single text line -> ViT18 image patches -> Vision Transformer -> GPT-2 decoder -> Generated text

What it is: TrOCR (Transformer-based OCR) is a deep learning model by Microsoft Research that combines a Vision Transformer (ViT) image encoder with a GPT-2 text decoder. Unlike Tesseract which was engineered with rules, TrOCR learned to read entire font training sets — millions of text images paired with their correct transcriptions.

How it works: The ViT encoder splits the image into ViT18 pixel patches and processes them as a sequence like words in a sentence. It learns spatial relationships between patches using self-attention. The GPT-2 decoder then generates text one character at a time, attending to the visual features. This approach is similar to how image captioning models work.

Best for: Single lines of text that are noisy, distorted, handwritten, or photographed at an angle. Crop your image to one line first using the Crop tool, then run this model.

High accuracy - Handles noise - Handwritten - Single line only - Slower

Tip: Use the Crop tool to select just one line of text. TrOCR reads the entire image as if it were a single line — if there are multiple lines, it may merge or skip them.



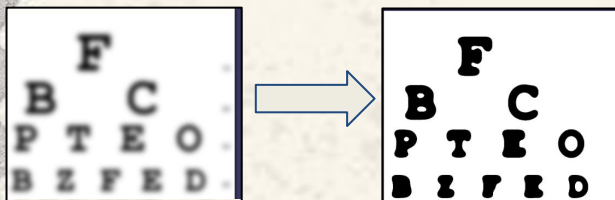
Appendix: Under-the-Hood View of SPARK

Edge-Device

(easy computing, low power, low memory)

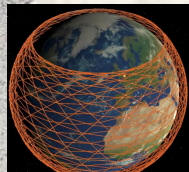
- Image collection
- Grayscale compression
- Noise deduction

Noise reduction by thresholding



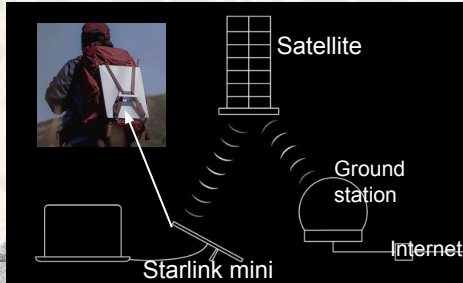
References: <https://encord.com/blog/image-thresholding-image-processing/>

"link" to Internet



Thousands of Starlink satellites to provide global, high-speed, low-latency internet.

Handley University College Edition



<https://www.realpars.com/blog/starlink>

"In-Cloud" AI

(sophisticated, larger memory, faster computing, enable sharing)

- run Computer Vision (CV) AI model on a remote powerful computer to read out word from pictures, known as Optical Character Recognition (OCR)

Traditional OCR (e.g. template matching)

Input sample character



Template characters in template database



A



B



C

AI-empowered OCR

Input image



Find features



Classify

- "1" X
- "2" X
- "3" X
- "4" X
- "5" X
- "6" X
- "7" ✓
- "8" X

References:

<https://blog.paperspace.com/clip/>

<https://www.itransition.com/computer-vision/ocr-algorithm>

- Recognize characters based on position, size, shape (pre-defined rules)
- Best for simple, clean text but not for dirty degraded text
- Cannot continuously improve
- Handle many different kinds of writing, including messy or damaged images
- Improve overtime with additional training data
- Complex, need large memory & fast computing on the remote ("cloud") computer
- **Can be shared:** cost effective access to best tech for all archaeologists!



For backup only: add relevant info to Appendix

Home computer <- starlink/satellite data <- mesh network <- camera project

The scientist explained that there is usually no direct access to starlink if the excavation site is under the ground, or deep in the cave. In that case, we may use a long cable or router-based local network (need research to understand the concept, like how people communicate on the airplane, or on the moon). Check out abstracts in the references [internet connection in "caves" "mesh network" - Google Scholar](#)

: [Wireless Mesh Networking Tests and Evaluation in the Karst Natural Caves of Southwest China | IEEE Journals & Magazine | IEEE Xplore](#)

Also, to anticipate situations without internet, we want to have microSD to save images
We also consider add LED on the device for taking pictures in dim places

Not sure about these [developed a second version that performs all the tuning directly on the device. After that, it can be plugged into a computer for OCR-based analysis. During the process of running ocr algorithms, we find there are versions developed for single line, multiple line ocr. So we add crop function before ocr .]



Appendix: Design Rationales

Our mission: protecting the past made easy and fast

We don't just dig up the past—we protect its voice in the exact moment it's found.

Using SPARK, archaeologists can recover the ancient words with a **portable** device **right away** before they crumble or fade further.

Why edge-device + cloud AI?

Small portable device:

- robust and can be carried everywhere

Flexibility:

- you can attach our device to drones to research hard-to-reach place

“Cloud” AI advantage:

- AI model living on remote computers can be super powerful without making our device too big
- Scientists can keep training to make it better

Data safety:

- Everything gets saved online so discoveries aren't lost

Sharing helps all:

- Archaeologists can share the pictures and AI improvements, this helps teams with smaller budgets do amazing work too

Ready to build now:

- All the technology pieces exist; we just need to connect them together like LEGO bricks

Remaining challenges

- Our SPARK tool works best in places where Starlink (internet from space!) can reach. The good news is that Starlink is covering more places every year.
- Otherwise, like inside a cave. we can put a small Starlink dish somewhere high up where it can "see" the sky, then use cables and routers (like internet stretchers!) to send the signal down to where the archaeologists are digging



Our Roles in the Project

Isabella: research of the problem; creation of artifacts for experiment

Mason: research of existing solutions for the problem

Luke: research of computer vision (CV); testing preprocessing & CV models

Claire: research problem, setup prototype with microcontroller as well as web app to integrate with different OCR algorithms,



Community Engagement

Special thanks goes to **Mr. Friedman**, who we interviewed before starting the project. He was kind to share his fun experience as an archaeologist, which includes finding an ancient toilet. He also gave us great suggestions for our project!



Charlie Friedman
History Teacher at RCDS

