Detecting Art Forgery Using Terahertz Lasers

Nate Coirier and Vivian Chen, EECS 388 Final Project Presentation

Northwestern University

CQD

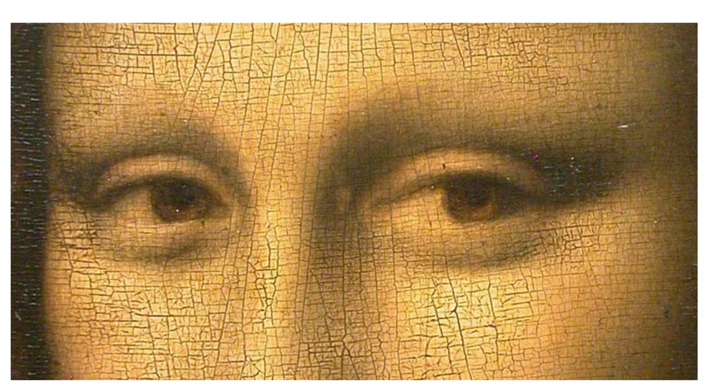
Northwestern Office of Undergraduate Research

Background

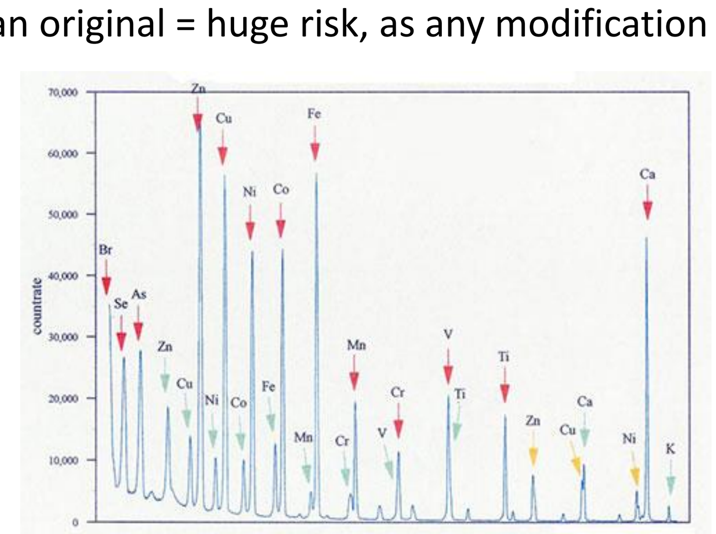
- Collectors and museums would like to recognize when items are forgeries so that they do not spend money on frauds
  - They often employ specialists in detecting art forgery to screen incoming works
- Forgery recognition requires a detailed knowledge of the history/work of the artist and materials available at the time when the artwork was allegedly created
- To counteract this, art experts rely heavily on various scientific methods

Historical Methods

- Morellian Analysis
  - Involves looking at characteristics of the painting which are often unique to the artist
    - Brush stroke directions, shapes of objects, etc
  - Although difficult, can theoretically be cheated
- Craquelure
  - The network of fine cracks appearing over time
  - Uses optical microscopy
  - Looking at how a painting has worn/ degraded over time to determine its time period and how it has been stored



- Mass Spectrometry
  - Separates out different elements and compounds used in the paint
  - The composition of the paint is compared to what was available at the time
  - Although precise, this method is also destructive, requiring a sample to be taken from the painting
  - Damaging an original = huge risk, as any modification can decrease value

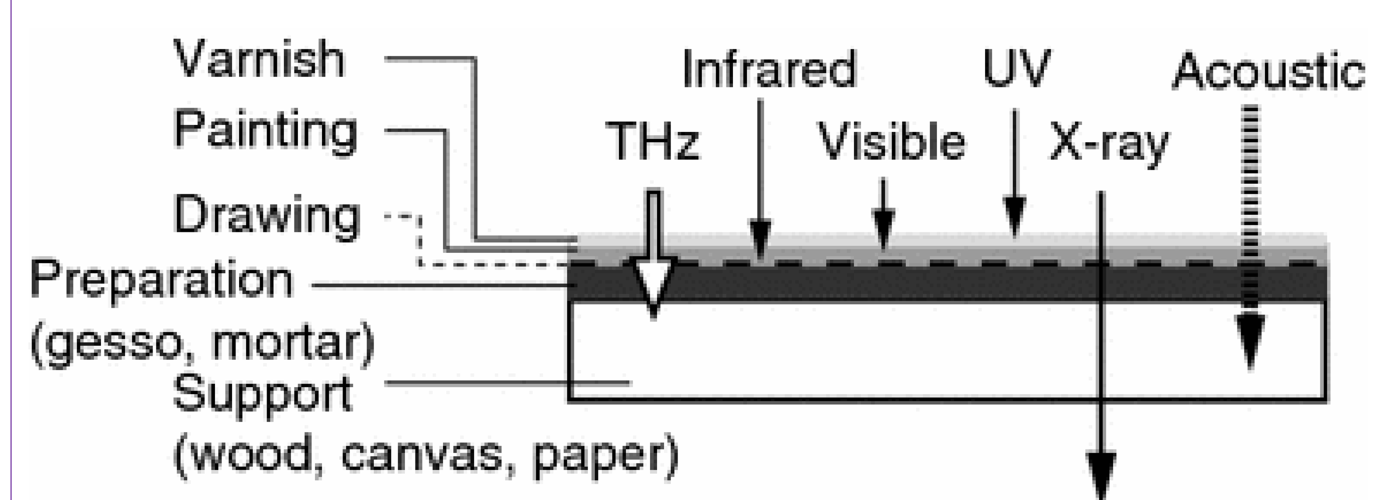


- UV Imaging
  - Old paintings have natural varnish layers that fluoresce strongly
- IR Imaging
  - Infrared rays penetrate surface and reflected back into sensitive camera, revealing details of underdrawings (effective for charcoal)
- X-Ray Imaging
  - Penetrate the surface of the painting
  - Underdrawings, pigment analysis
  - Requires specific instrumentation

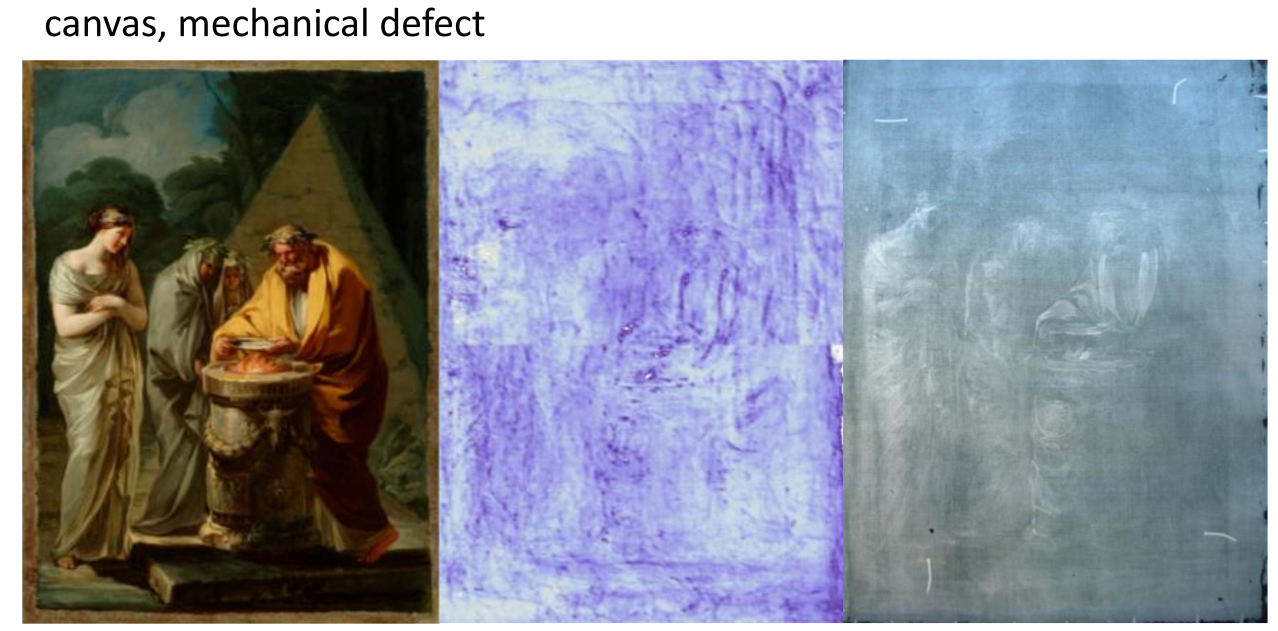
Methodology

Terahertz Spectroscopy:

- Penetrates through dielectric materials (fabric, paper, plastic, wood), highly reflective, non-ionizing, low energy
- Non-contact, non-intrusive, non-invasive method
- Can see underdrawings, signatures, defects, repairs, inclusions of heterogeneous materials, porosity, fiber orientation (less evident with other techniques)
- Can detect thickness, materials/pigments



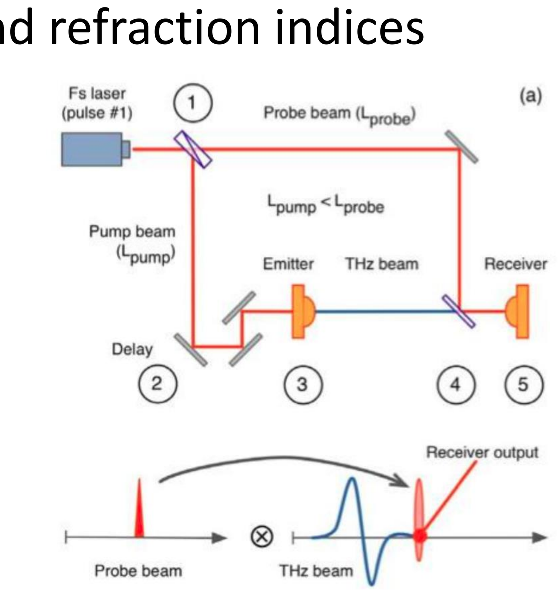
- With THz, one can distinguish the main strokes that give shape to the figures in the artwork, signature, interaction of the wooden frame with the canvas, mechanical defect



- X-ray image (right) in which alleged signature is not visible nor wrinkles and defects on the upper third sector

System Working Principle

- THz laser emitter delivers THz pulse
  - Implemented as time-domain (TDS) or frequency-domain (FDS)
- THz-TDS: pump-probe approach
  - Pulse measured for a particular time difference between the probe and pump
- Returned frequencies then FFTed to isolate the relevant frequencies and to determine differences in the absorption and refraction indices

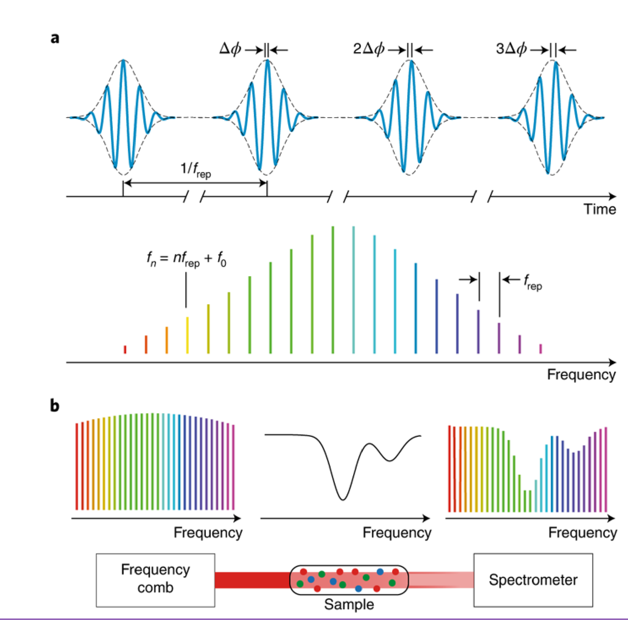


Issues with THz Devices

- High temperature operation for lasers
  - Basic THz lasers often need to be supercooled to liquid nitrogen temperatures (~77K) in order to be effective
  - This is due to the emission of phonons at high temperatures, relaxing electrons to lower subbands and reducing the gain of the laser
- Laser Gain Cavities
  - Current devices use metal- metal waveguides
    - Good thermal/ heat sinking properties, allows high temperature use
    - Has a large impedance mismatch with free space, causing divergent beams
  - A proposed solution is to use high-order DFBs
  - Another proposed solution is to add an integrated collimating lens in fabrication/ post processing
- High Temperature Operation for Detectors
  - At room temperature and above, dark current often causes significant issues with signal integrity
  - One way they are trying to remove this is by introducing different kinds of "barrier" layers into device structures
    - These then limit the amount of carriers at high enough energy to move across the junction and be detected
    - Increases the amount of electrons that must be present for detection to occur
  - We are now looking towards Type 2 materials to get this kind of performance

Future Improvements

- We anticipate industry using frequency combs
- Researching new device structures and material systems
- It is lucky that high- profile applications such as these exist to fund research, so that the benefits of this technology can be later scaled
  - In specific, room temperature detection/ generation will allow this to be commercialized



Sources

- https://en.wikipedia.org/wiki/Craquelure#/media/File:Mona_Lisa_detail_eyes.jpg
- https://link.springer.com/article/10.1007/s00339-015-9558-5
- https://www.osapublishing.org/DirectPDFAccess/E51BB0EF-9057-983B-1CD1B5583F72ACA3_259467/oe-21-15-17800.pdf?da=1&id=259467&seq=0&mobile=no
- McHugh, M., DiFrancesco, G., Gencarelli, J., & Debenham, C. (n.d.). "Art Forgeries and Their Detection." Retrieved February 25, 2019, from https://nature.berkeley.edu/garbelottoat/wp-content/uploads/art4.pdf
- Ragai, Jehane. "The Scientific Detection of Forgery in Paintings." Proceedings of the American Philosophical Society, vol. 157, no. 2, 2013, pp. 164–175. JSTOR, www.jstor.org/stable/24640239
- Cosentino, Antonino. "Terahertz and Cultural Heritage Science: Examination of Art and Archaeology." MDPI. https://pdfs.semanticscholar.org/79aa/dc79f86921a367f479d3d146b412bfb0ec98.pdf
- Peiponen, Kai-Erik, et al. Terahertz Spectroscopy and Imaging. Springer Berlin Heidelberg, 2013.
- Razeghi, Manijeh. Technology of Quantum Devices. Springer-Verlag New York, 2016.