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HOLOMAKERS PROJECT

Motivating secondary school students towards STEM careers through hologram making and innovative virtual image processing practices with direct links to current research and laboratory practices

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Activity 2

From an abstract pattern to a more familiar representation: the "circulation of the 4 cultural artefacts" project

Project description for teachers

Overview

This activity is one of the interdisciplinary projects in STEAM for computer generated holograms that will be developed within the context of the Holomakers project.

In this project, we expect from the students to become familiar with the basic principles of optics and computer generated holograms, by getting motivated through a game of exchanging cultural information via encrypted messages. The encrypted messages will be holographic patterns derived from based on Fourier transform Gerchberg–Saxton (GS) algorithm on images of physical cultural artefacts. This project will be executed/ performed in two phases and the *GNU Octave* software will be the basic operating tool. This project is a playful approach to computer generated holograms and includes a set of preparatory tasks for future analog hologram making.

Est. Duration	**2-3 hours**
Equipment needed	Octave, simple camera,
Links to external files	All the folders and files needed are in Dropbox **O3>Projects>Cultural Artefact** https://www.dropbox.com/sh/9clv83ukp2047gq/AABmCf9Ap_e9WWXWDV39jilwa?dl=0
Learning objectives	We expect students to: • get familiar with the procedures of producing a computer generated hologram • understand what a holographic interference pattern is • get familiar with the basic operations of GNU Octave software for computing a holographic interference pattern • understand how to re-construct a holographic interference pattern • problematize upon the interference concept • practice their collaborative skills towards producing a text that will come along the holographic pattern
Preparation needed	The teachers should recall the knowledge gained during C1. They just need to become familiar with the process using images &calculated patterns as well as the scripts available in the 'Examples' and in the 'Scripts' folders in the Dropbox (O3>Projects>Cultural Artefact>…)

Preparatory phase

In Dropbox (see folder O3>Projects>Cultural Artefact>Examples / direct link: https://www.dropbox.com/sh/papztdg0vx3qu38/AAB0mK57Nnlb93maYyiz1naza?dl=0) there are several holographic interference patterns that can be used to familiarize yourself with the process that should be undertaken in the class (see Phase1 and Phase2). You can also trigger students' curiosity by demonstrating the process using material available in this folder.

Phase 1: Receiving a strange message from another country

At the beginning of the first phase, students will receive an image of a strange pattern (like the one presented in Figure 1) together with a short description (either separately or above it). You will be actually the one that you will direct them to this 'strange gift'. All the patterns and corresponding texts will be available on Dropbox (see O3>Projects>Cultural Artefact>OurGifts>….team > encrypted).

Scenario: *Maria is a Greek teacher. She opens the 'OurGifts' folder and selects the encrypted message from Poland (OurGifts>Polish team>encrypted…). She takes the pattern and the text. She then tells to her students that the pattern and the text were prepared by the students in Poland". Will they accept the challenge? Are they in position to decode the message that has been sent from Poland?*

The students are informed that this is an encrypted image/picture, sent from another country, and is currently appeared as a holographic pattern. Therefore, if they want to reveal/discover its content they need to get familiar with some basic principles of optics and particularly with Fourier transform, as well as with procedures related to computer- generated holography (GS algorithm).

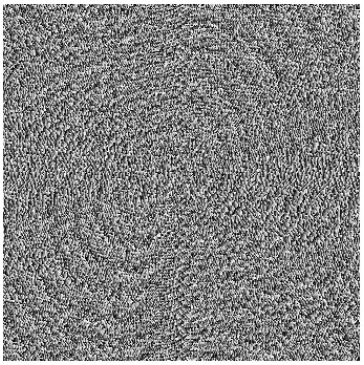


Figure 1 Calculated pattern

Decoding the message

The students are informed that the aforementioned holographic pattern is actually a calculated pattern, produced with the help of GNU Octave software. So, they need to comprehend a few basic operations of this software in order to decode the encrypted image.

GNU Octave Software is a high-level language primarily intended for numerical computations. It is typically used for such problems as solving linear and nonlinear equations, numerical linear

algebra, statistical analysis, and for performing other numerical experiments[1]. In our project it will be implemented as a converting tool that will reconstruct an image based on calculated patterns and vice versa.

Initially, the students are asked to open the GNU Octave software and shortly explore some of its basic features, such as the command prompt, the command line and/or how to start and/or import an Octave session. It is very important to set the working folder (the folder where students will store all Octave files and images. To do this, click the blue icon in accordance with Figure 2 and then select the appropriate folder (you can, for example, create and choose the folder C: \ HOLOMAKERS \ Octave).

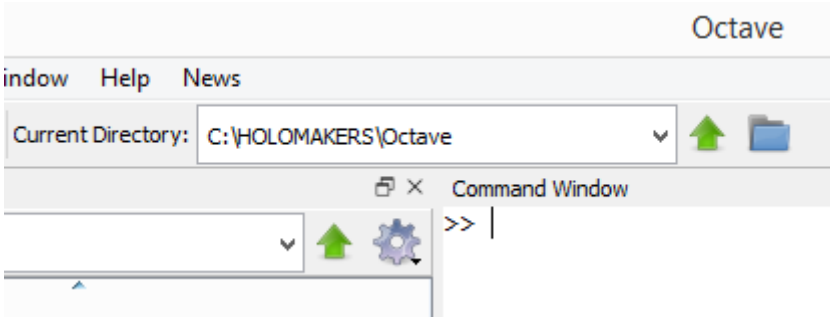


Figure 2: Changing the working folder

Next, the students are asked to copy to the working folder all files from the O3\Projects\Cultural Artefact\Scripts folder. Now they are ready to open the file "*CGH_reconstruction.m*" and examine the code contained on the editor window (Figure 3).

[1] https://www.gnu.org/software/octave/doc/interpreter/Introduction.html#Introduction

```
1  pkg install image
2  pkg load image
3
4  CGH = imread('CGH.bmp');
5
6  A=fft2(ifft2(CGH));
7
8  Phase=abs(A)*2*pi/255;
9
10 GaussianBeam = imread('GaussianBeam.png');
11 GaussianBeam = rgb2gray(GaussianBeam);
12
13 Source=fft2(ifft2(GaussianBeam));
14
15 B = abs(Source).* exp(1i*Phase);
16 C = fftshift(fft2(fftshift(B)));
17
18 figure(1);imshow(abs(C),[]);title('reconstruction');
```

Figure 3: Reconstruction of the Computer Generated Hologram

Teachers should briefly, and **without going into detail,** explain them the logic behind this code. Then, the students will be requested to modify certain lines of the code. Specifically, they should focus on **line no 4** that is this part of the code: `CGH = imread('CGH.bmp')`. In order to load the image of the calculated pattern, the file CGH.bmp should be replaced with the encrypted image.

After editing/modifying the code on the editor window, they have to press the “run and save” button  in order to save the modifications.

A new window pops up, containing an image of the reconstructed hologram. The pattern has been transformed to a specific picture, depicting a cultural artefact.

Outcome: At this point, the student should have become familiar with some processes of computer generated holography. The focus is not on programming or understanding the code but in understanding that a pattern or something that looks complex, can convey useful information and under some mathematical calculations, it can be translated into something more familiar to us. You can also encourage your students to think the role of the computer as a means of performing complex calculations.

Phase 2: Replying/responding to the initial message

In this phase of the projects, students are requested to respond to the received message by creating and sending their own encrypted message.

Selecting the artefact

Each school/department will choose a representative cultural artefact that would like to send to another school/partner of the community in order to reply to the received message as well as to share/exchange (some significant) cultural information. Students should be encouraged to do a short research in order to become more engaged to the entire procedure, but keeping in mind that the artefact should be a physical object that is easily accessible and that can be easily captured on camera. An example of such artefact is presented in Figure 4.

Figure 4: Cycladic statue – example of a cultural artifact

Capturing the artefact

Once the cultural artefact is found, the students – with the help of their teachers – are asked to take a picture of it in a rather neutral background (eg. a black canvas). Then the picture should be prepared in the following way:

- Size of the image **must have** dimensions of **1024x1024**
- Format can be either bmp or jpg
- Image should be either grayscale or binary (black background and white artefact)

Writing a short description

Next, students should be encouraged to write a short description of the object that will be attached to the holographic/digital pattern. The description should be short; it should not reveal too much; it can reflect key historical/cultural information. (An example for Figure 4*: I am immobilized for almost 5.000 years. I was found in….etc)*

Creating the holographic pattern

Students are asked to open again the GNU Octave software and specifically the file GS_Algorithm *.m*. The script contains GS algorithm for calculating pattern of CGH.

This procedure is presented in the Figure 5

```
1  pkg install image
2  pkg load image
3
4  GaussianBeam = imread('GaussianBeam.png');
5  GaussianBeam = rgb2gray(GaussianBeam);
6
7  StartPhase=zeros(1024,1024);
8  StartPhase=fft2(ifft2(StartPhase));
9
10 Source=fft2(ifft2(GaussianBeam));
11 Source = abs(Source).*exp(1i*angle(StartPhase));
12
13 TargetImg = imread('holomakers.bmp');
14 Target=fft2(ifft2(TargetImg));
15
16 A = fftshift(ifft2(fftshift(Target)));
17 for i=1:10
18   B = abs(Source).* exp(1i*angle(A));
19   C = fftshift(fft2(fftshift(B)));
20   D = abs(Target).* exp(1i*angle(C));
21   A = fftshift(ifft2(fftshift(D)));
22 end
23
24 figure(1);imshow(TargetImg);title('Original Image');
25 figure(2);imshow(angle(A),[]);title('Calculated Hologram');
26 figure(3);imshow(abs(C),[]);title('Reconstructed Image');
27
28 A=angle(A);
29 A=A-min(A(:));
30 A=A/max(A(:));
31
32 imwrite(A, 'CGH.bmp');
```

Figure 5: GS algorithm for calculating pattern of CGH

The students have to modify line no 13 so as to import the captured image. Once they finish editing, they will select "*run and save*" command in order to execute the modification. The extracted figure will be the calculated holographic pattern of the selected cultural artefact. This pattern will automatically save in the file *CGH.bmp* (see line no 32 of the code).

Accomplishing the project

After saving the figure of the calculated pattern, transfer the pattern and the short description in Dropbox (O3> Projects>Cultural Artefact>OurGifts) in the appropriate folder. Obviously, four (4) folders are available one for each team: Greek team, Spanish team, Italian team, Polish team

For example:

Andrea is an Italian teacher. He transfers the encrypted message, which is actually includes 2 files (the pattern and the text file) into the folder 'encrypted' following this path O3>Projects>Cultural Artefact>OurGifts>Italian team>encrypted". So that the other teams to find it and to decode it.

Optionally, you may also consider to prepare your encrypted message in the following doc/ docx format (see Figure 6). You can also upload this in dropbox in the corresponding file. **Why should we do this?** In this form your encrypted message can be more easily printed out and used at a later stage (preparation of physical hologram).

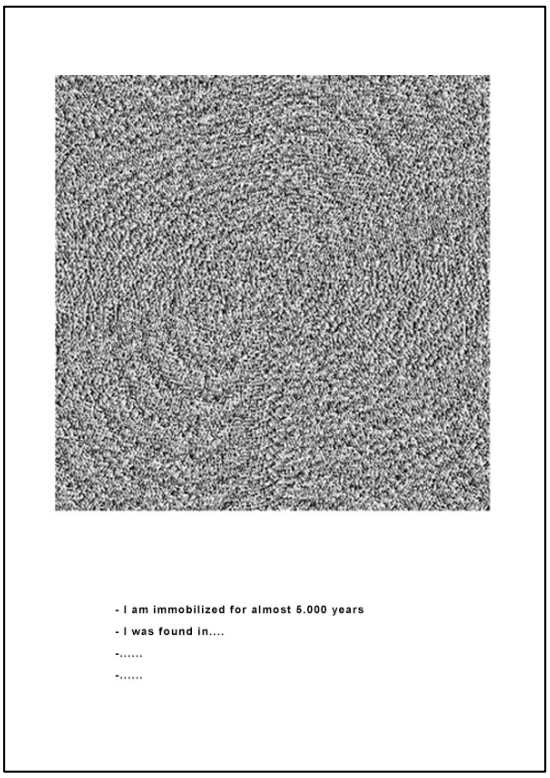


Figure 6: Example of printed A4

Discussing students' experiences in class

After accomplishing the project, the students should be encouraged to discuss and share their experience with their teachers as well as with their classmates. It is important to provide

the link between this experience and the forthcoming activities and to smoothly introduce them in the next steps the physical hologram making.

Here are some questions that can be addressed to the students:

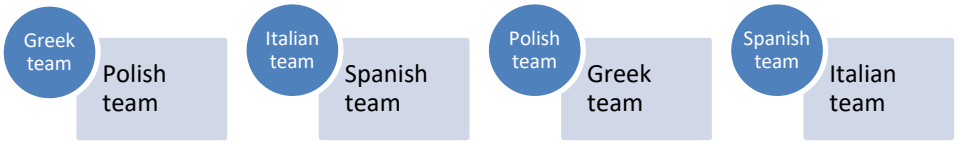
Can you describe the process in your own words?

What is the most challenging part in this process?

Can you think of similar activities where encrypted messages are used?

Practical issues and timeline

In case the time is rather limited and you cannot practice the aforementioned procedure for all the encrypted messages developed by the partner schools (which is the recommended), here is a scheme for doing it:



Scenario:

Jose is a Spanish teacher and Andrea is an Italian teacher. Jose checks the folder 'Italian team>encrypted' in order to take the encrypted message prepared by Andrea's class. In a similar way, Andrea checks the folder Spanish team>encrypted in order to take the encrypted message prepared by Jose's class.
Similarly, Maria from Greece checks the 'Polish team>encrypted' folder and Anna from Poland checks the 'Greek team> encrypted' folder.

They are careful not to accidentally erase any file/folder

Declaration

This document has been prepared in the context of the HOLOMAKERS project. Where other published and unpublished source materials have been used, these have been acknowledged.

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