# Bridging Engineering and Extended Reality Using the 2D Heat Equation

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## Introduction/Abstract

Extended Reality (XR) is a quickly growing field with implications of a new and more interactive method of learning. This includes the potential for implementing real world science and engineering problems into an immersive format that can bridge the gap between extended reality and practical engineering skills [1].

To delve into this idea, this project focuses on a simple physics concept and explores ways in which to make it interactive in order to create a more fundamental understanding while also portraying it in an engaging way. Specifically, this project explores the 2D heat equation, seeking to make an interactive online interface and proposing its implementation in extended reality.

The heat equation is an equation that models the diffusion of heat throughout a given body or region. This project seeks to demonstrate this process in a simple and interactive way.

## Research Aims

- Create a simple and interactive graphic to visually represent the 2D heat equation
- Utilize current XR capabilities to propose a method by which to implement that graphic into extended reality

## Methodology

For this project, the code for the interactive simulation was laid out using the MATLAB software. This then allowed for testing and modification of the code as needed. A GitHub repository was also opened to display the code on a public domain.

Link to GitHub Repository

## Results

The figures below demonstrate the default setup of the interactive graphic. Figure 1 is more suitable for easy use with a mouse, while Figure 2 is designed to more simply be done with a mouse pad or even touch screen. In each of these figures, there is a color scale from 0 to 1, 0 being representative of the "coldest" temperature and 1 of the "hottest". The default background color has a value of 0.5.

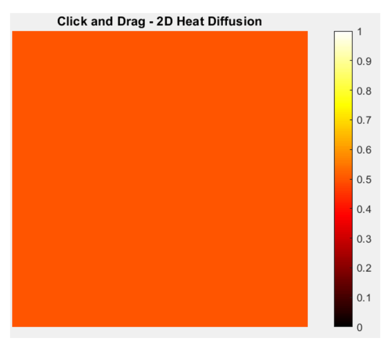

**Figure 1.** Default graphic. Users can interact by clicking and dragging their mouse. Left-click results in a value of 1, while middle-click/shift+click results in a value of 0. A brush stroke can be halted with a right click.

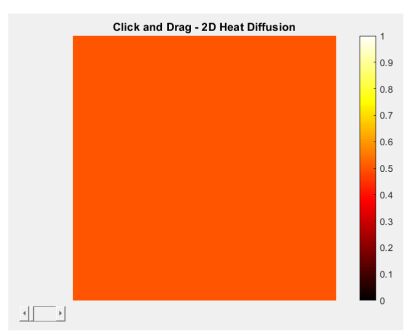

**Figure 2.** Default graphic. Users can interact by clicking and dragging their mouse. Moving the slider will adjust the value, allowing for a wider variety of values.

Drawing on the borders presents a unique opportunity to represent a heat source (or cold, depending on the value). And example of this can be seen in Figure 3.

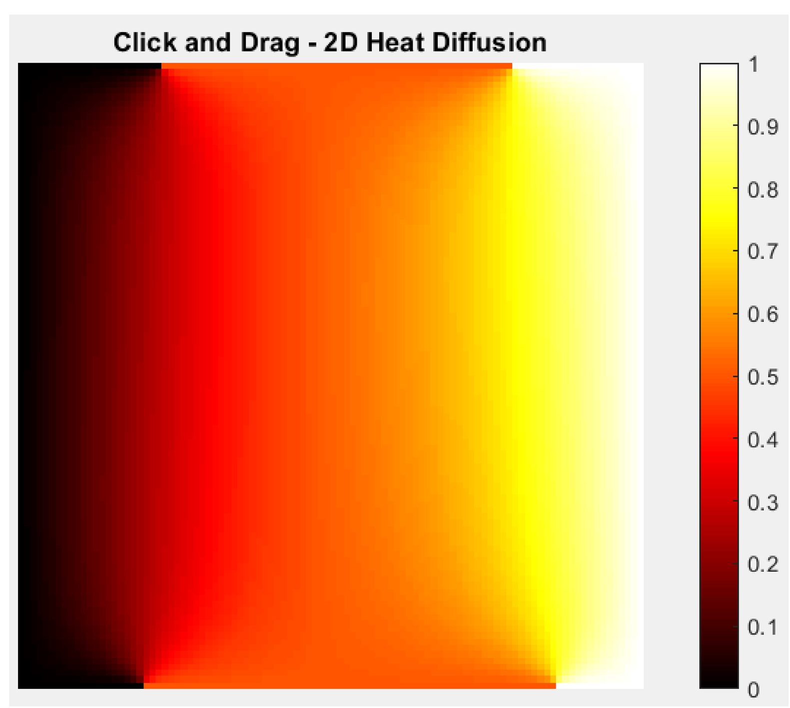


**Figure 3.** Example of graphic with a heat source at the right end and a cold source at the left.

Thus the student or user can watch the diffusion of heat throughout shapes and designs they create themselves.

In addition, the code provides opportunities to change certain presets such as the default temperature, diffusion coefficient, brush size, and rate of diffusion.

## References

1. The Project. Alliance4XR. (n.d.). https://alliance4xr.eu/the-project-2/

## Discussion

These two codes provide 2 different yet similar ways to view and interact with the heat equation on a 2D scale. It lays the groundwork for future programs such as XR to have a fundamental code to build upon.

## Conclusion

This project spelled out the code necessary to model an interactive graphic of the heat equation in two dimensions. It allows for user interaction to demonstrate this concept by using a mouse to draw or paint on the figure, with the capability of changing the heat of the brush as well as other constraints. With this code now established as a background, this code can be modified as needed to run in different programming languages, such as Python or JavaScript, as well as to fit in three dimensions and/or in extended reality.

## Future Work

This project currently just scratches the surface as to the potentials of interactive virtual learning. Some of the goals for future work include:

1. Converting this code to a format more fitting for extended reality, such as programming it in JavaScript.
2. Using hand tracking extended reality technologies to allow the user to press their hand against a surface and watch the heat diffuse. This can be done by using different joints/points on the hand as "hot spots".
3. Creating 3-Dimensional models of this code to be used in practical university level courses, such as thermodynamics, as a teaching and learning tool.

There are many ways that this code can be expounded upon in the future to more successfully bridge the gap between the realm of extended reality and the scientific and engineering properties of heat. This project presents a jumping point off of which more innovations can be made.