AR-SPICE Circuit Simulator

A framework for learning electric circuit fundamentals

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Project: *A Framework for Mixed Reality Aided Tools to Stimulate Learning Electric Circuits Fundamentals*

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References

[1] 'Microsoft HoloLens', Microsoft, 2018. [Online]. Available: https://img-prod-cms-rt-microsoft-com.akamaized.net/cms/api/am/imageFileData/RE1GJzk?ver=8b59&q=60&m=6&h=600&w=1399&b=%23FFFFFFFF&l=f&o=t&aim=true. [Accessed: 01-Sep-2018].

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OVERVIEW

The research presented describes an augmented reality (AR) application for learning electrical circuit fundamentals. The application was developed for the Microsoft HoloLens platform, leveraging its hardware accelerated spatial mapping and embedded video capture capabilities with the Unity3D toolkit. Our research combines existing work on circuit simulation tools for education with the HoloLens' ability to integrate into real-world processes. We aim to increase the learner's conceptual understanding of circuit fundamentals and help relate components in simulated circuits to real-world circuits.

(Fig. 1)
Microsoft HoloLens AR headset [1]

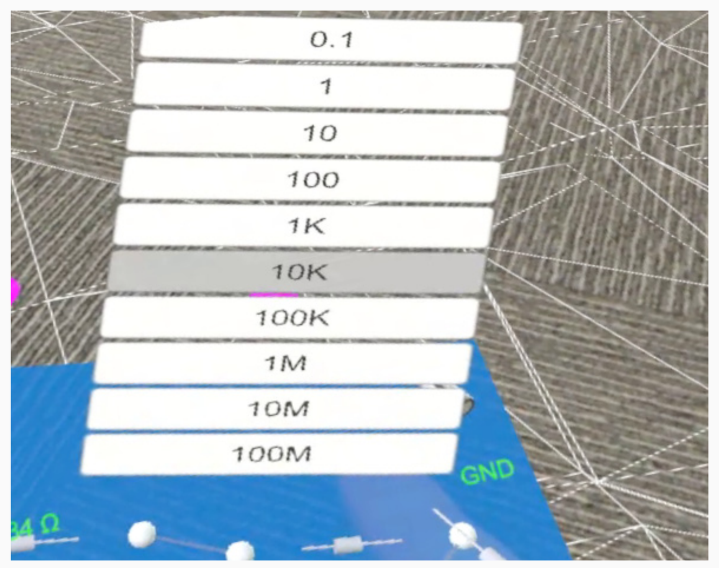
PROBLEM

Technology can be used to bridge the gap between theory and real circuit design, as it is vital for students to be able to see the effects of changing circuit parameters [2]. There is evidence that simulations improve student motivation, and help develop an improved conceptual model [3], [4].

HOLOGRAPHIC INPUT MODULE

The main input method in the application is through the holographic input module. This input method is similar to a traditional SPICE simulation tool, where component tools are selected with the input device and the components are instantiated where the user specifies. Currently there are various basic placement tools such as resistors, batteries, wires and a component parameter entry tool. There is also a trash bin so that users can remove components.

Placement of components is a two-step process involving the user selecting the tool and then the position to place the component. Connections between components are done through a wire tool. To speed up circuit building, the wire tool links components according to the movement of the users input pointer, allowing wires to be 'drawn'. Component parameters are set through an incremental system where values are selected from a list and narrow down to a specific number (Fig. 2).



(Fig. 2)
Resistor resistance value entry

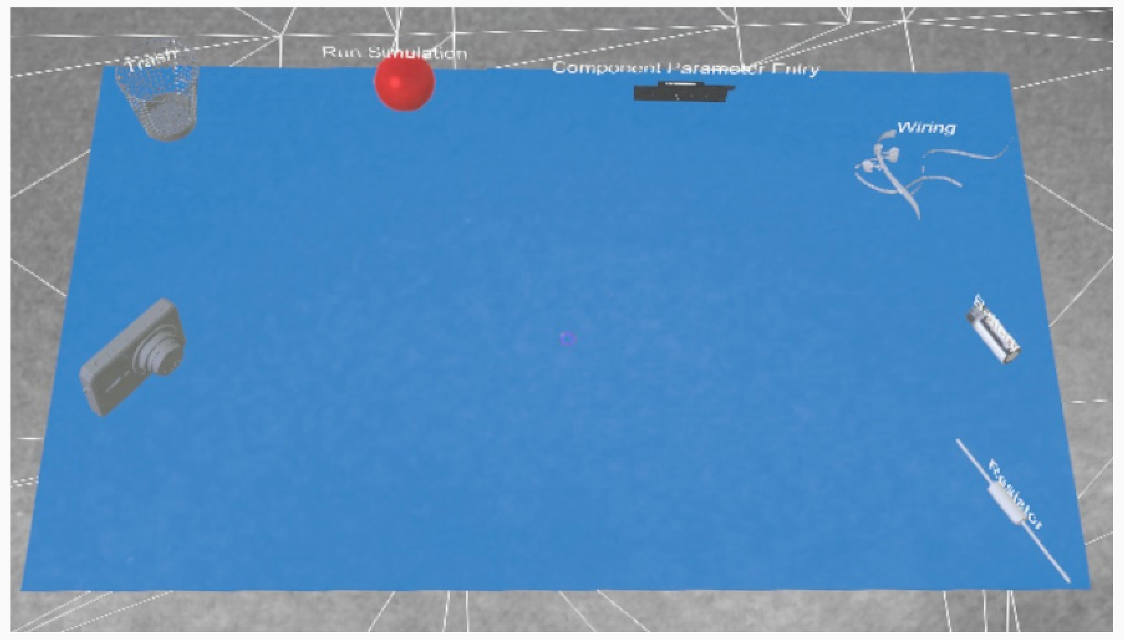
BREADBOARD INPUT MODULE

In addition to the AR-SPICE system accepting user input through placement tools, a breadboard input module has been developed that aims to use real-world information to speed up the circuit building process. The end goal of this module is to be able to provide a one-to-one binding between real-world breadboard components and simulation circuit components, which would allow the overlaying of simulation values.

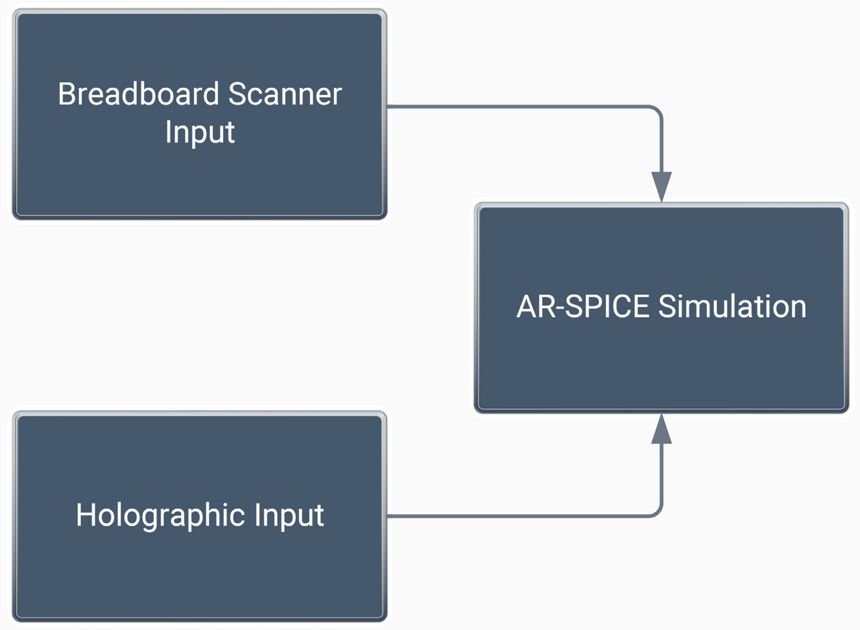
Currently, the input system uses a combination of markered and non-markered detection algorithms to pick up resistor components on a breadboard. Using the embedded camera, the user can take images of a marked breadboard that is then processed by the input module. Resistor components on the breadboard are then recognized through a computer vision algorithm based on colour recognition.

The prototype has several constraints including lab lighting conditions, component placement orientation, and can only detect specific teal resistors.

AUGMENTED REALITY SIMULATION ENVIRONMENT



(Fig. 3a)
AR-SPICE circuit simulator workspace



(Fig. 3b)
AR-SPICE circuit simulator system modules

User Interface

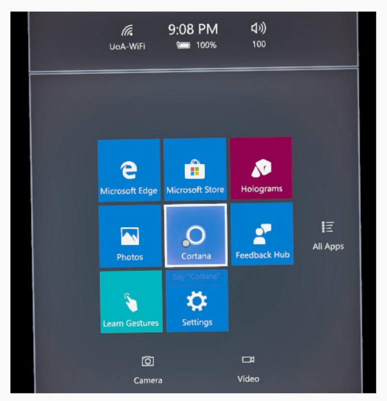
The user interacts within the environment with the HoloLens' default finger tap gesture ('air tap'). The input pointer is locked to the user's gaze and moves as the user looks around (Fig. 3d). A virtual mat acts as a ground for the environment (Fig. 3a).

Component Graph

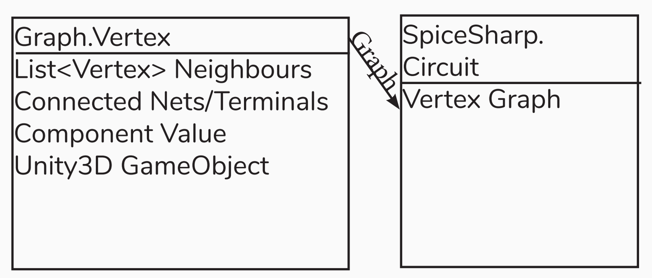
An abstract component graph connects the models from the input module to the SPICE model. Each graph node represents a circuit component, containing information on its terminal connections and component parameters (Fig. 3e).

SPICE Simulation

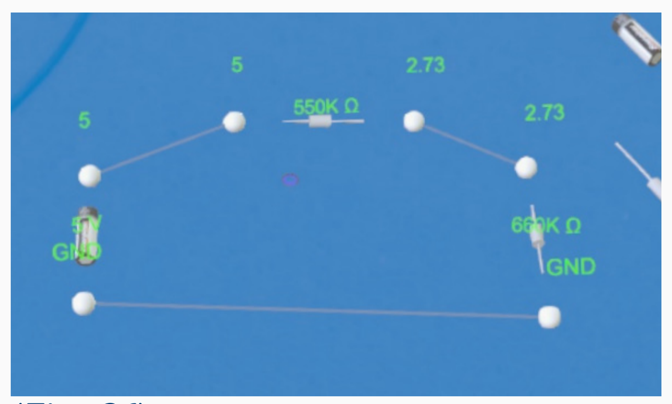
The simulation itself was developed with the SpiceSharp library. DC analysis can be performed on the simulated circuit once it is built, allowing users to see voltage values at different circuit nodes (Fig. 3f).



(Fig. 3d)
HoloLens input pointer on menu



(Fig. 3e)
Component graph classes

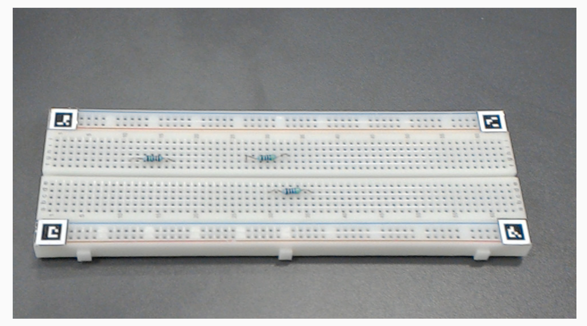


(Fig. 3f)
Virtual circuit after SPICE simulation

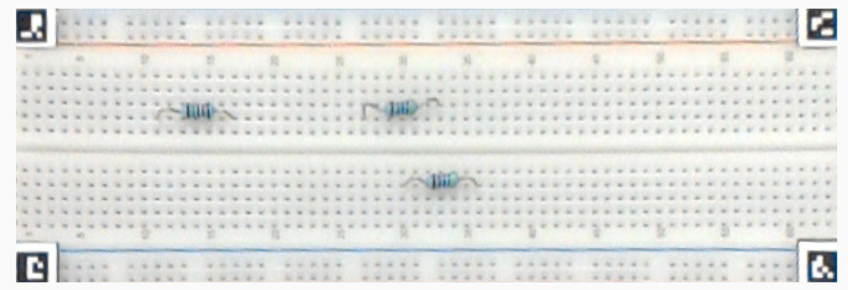
COMPONENT DETECTION PIPELINE

Significant time has been dedicated to developing a way to recognize breadboard components. The current implementation uses the open-source OpenCV library for detection. The use of a convolutional neural network (CNN) has been tested but has not been integrated.

The detection process first involves the use of a perspective transformation to correct any perspective distortion on the breadboard image, transforming the view from what the camera sees (Fig. 4a) and re-projecting it to a top-down view of the breadboard (Fig. 4b).



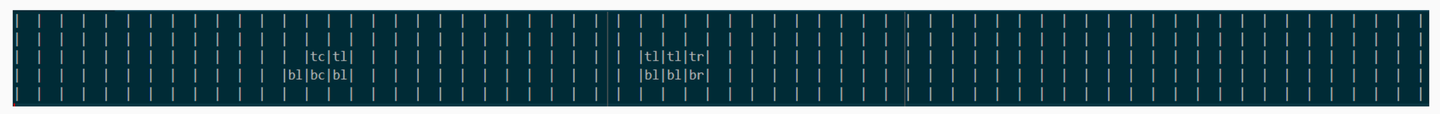
(Fig. 4a)
Camera image (cropped)



(Fig. 4b)
Perspective transformed image

A 'blob detection' algorithm is then used to detect the breadboard's holes, with heuristics used to deal with any abnormalities based on the expected regular grid structure of the breadboard (Fig. 4c). The image is chunked, with an area around each hole being a candidate for component classification. Color thresholding is used to identify chunks that contain components, currently limited to resistors (Fig. 4d). These multiple chunk classifications are then collected into component detections and listed.

(Fig. 4c)
Breadboard chunk segmentation grid



(Fig. 4d)
ASCII representation of the array of chunk classifications (t = top, b = bottom)

FUTURE RESEARCH

The application has a bare bones interface that can be further developed to provide a better user experience, which includes tooltips for guided use. A mapping between real-world and simulation components needs to be developed, such that information can be overlaid on top of the breadboard. Support for more components can be added into the system,

Additionally, there is a need to perform a user trial on the system to assess whether it accomplishes the goal of improving student motivation and understanding.