Solderless Breadboard Debugger

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Introduction

Solderless breadboards are widely used tools for circuit engineers to create temporary prototypes and experiment with circuit design. Breadboards have aligned holes on its surface and each row is connected inside the breadboard. One can plug-in various of circuit elements to form a complete circuit.

Objective:

Our general goal is to build a tool to help users to decide whether they have build their circuit correctly compared to their design.

The task includes detection and classification of certain objects in the image and associate image coordinates with breadboard hole indexes. These include the detection of

- Location of the plug-in holes
- Endpoint location of wires
- Location and resistance of resistors
- Location and type name of IC chips

Using the retrieved information from above, we could then

- Reconstruct circuit tree schematic
- Detect difference between schematics

Location of Plug-in Holes

The plug-in holes form the fundamental grid restricting the location of all other components on the breadboard. It is crucial that we obtain accurate estimation of plug-in holes first. The steps include

- Convert into black & white image
- Detect key characters via OCR
  - Text marker '+' '-' 'A' 'E' 'F' 'J'
  - Digit marker '1' '5'
- Detect circles via CHT
- Construct plug-in holes grid

OCR Result

Location of Wires

Detection of wires are similar to resistors, the key difference is we define wires as longer and thinner shapes.

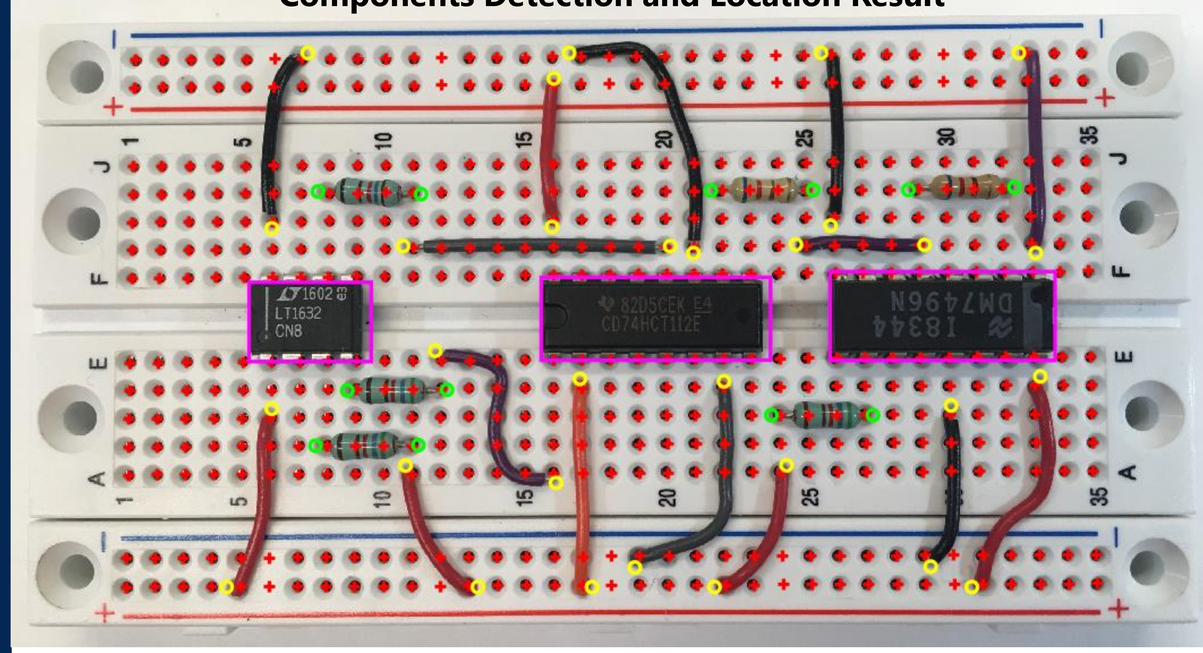
Location and Type Name of IC Chips

IC chips are the most common components in circuit design. They are largest in area and rectangular in shape, with 8 or 16 pins on their longer edge. Each IC chip have its type and manufacturer name printed on the top. Their locations are restricted to the center rows of the entire board. The detection and recognition steps include

- Preprocessing: smoothing and converting to binary image
- Find connected components and remove small objects
- Perform rectangular-shaped morphological close operation
- Filter areas by dimensionality and aspect ratio
- Detect direction and type name of each IC chip via OCR

IC Chip OCR Result

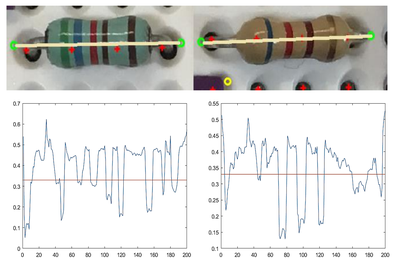
Components Detection and Location Result



Location and Resistance of Resistors

Resistors are often found in circuit design. For resistors, two most critical parameters, positions of the endpoints and resistance, need to be determined in order to reconstruct the circuit schematic accurately. The steps include

- Perform boundary function to partition the binary image
- Detect resistors by comparing the area, as well as width and length, of each partitioned region with a reference resistor
- Use centroid, orientation and major axis length of the resistor region to calculate the exact position of the endpoints



Color Band Variation Result

- Run interpolation across the center of the resistor passing through two endpoints to find the color band intensity values
- Determine the resistance value according to the color band variation across the resistor

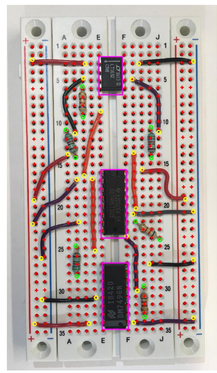
Circuit Tree Reconstruction

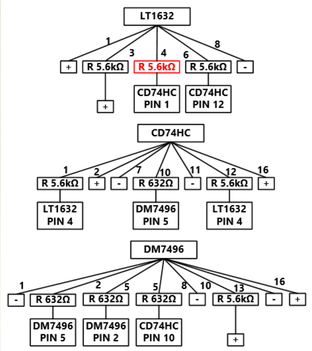
After the components of the circuit are recognized, the coordinates of all components will be sent to the circuit checking algorithm, which will test if the circuit is organized as it is supposed to by building several circuit trees rooted from each chip. The process of reconstructing the circuit trees include

- Every circuit tree starts from a chip
- Every child node is either a circuit element (resistor/chip) or power bus ('+'/'-') connected to the chip or other components
- Stop building the branch when reaching '+'/ '-' terminal or any other chip pins
- Run tree comparison algorithm to check whether the circuit tree generated is the same as the ground truth tree

Final Results

Board (A) Reconstruction Result





Board (B) Reconstruction Result