Designing a Sketch Based Interface for Electronic Circuit Simulation

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1. Project Background

Simulation is a well-known and useful computer-aided design (CAD) tool for analysing electronic circuits. However, ease of use and speed of prototyping are two major drawbacks of circuit simulation using traditional CAD tools.

Additionally, there is an increasing trend in the use of machine learning tools to aid research and development [1]. It is therefore desirable to develop a tool that uses machine learning to aid researchers and students in the design of electronic circuits.

2. Existing Solutions

There are a number of existing solutions that are similar to the project outcome. These methods each have their own merits and drawbacks, as detailed below:

- **Programmatic**: [2]: using properties of the shapes of the components to identify
- **Support Vector Machines**: [3]: using a Support Vector Machine (SVM) to classify
- **Object Detection**: [4, 5]: using deep learning with object detection

These approaches either require intimate knowledge of the geometry of the components and the image processing techniques required to extract the relevant information from the sketch, or do not provide a complete product that provides a simulation from the input image.

3. Aims and Objectives

This project aims to produce a software tool that receives hand-drawn circuit diagrams as input and generates an LT-SPICE simulation file as output, which will be paired with a compatible backend to produce a circuit simulation. The user will be able to:

- Create a hand-drawn schematic using a sketching interface
- Pass the sketch to the application via camera or file upload
- Observe the resulting simulation on their device

4. Evaluation

The object detection phase of this project uses You Only Look Once (YOLOv8) [6], a state-of-the-art object detection algorithm, evaluated using the mean average precision (mAP) metric. The metric requires the ground truth bounding boxes to overlap with the predicted bounding boxes by a certain amount, known as the intersection over union (IoU) metric. The mAP metric is calculated as follows:

$$\text{IoU} = \frac{A_{\text{intersection}}}{A_{\text{union}}} = \frac{A_{\text{intersection}}}{A_{\text{ground truth}} + A_{\text{prediction}} - A_{\text{intersection}}}$$

$$\text{mAP@0.5} = \frac{1}{N}\sum_{i=1}^{N} \text{AP}_i, \text{given IoU} > 0.5$$

This metric is a balanced measure of the model's ability to make correct predictions, (precision) but also how thoroughly it is able to detect all instances of the object in the image (recall). During training, this metric is one of the maximisation goals, which ensures that the model is able to make accurate, consistent predictions.

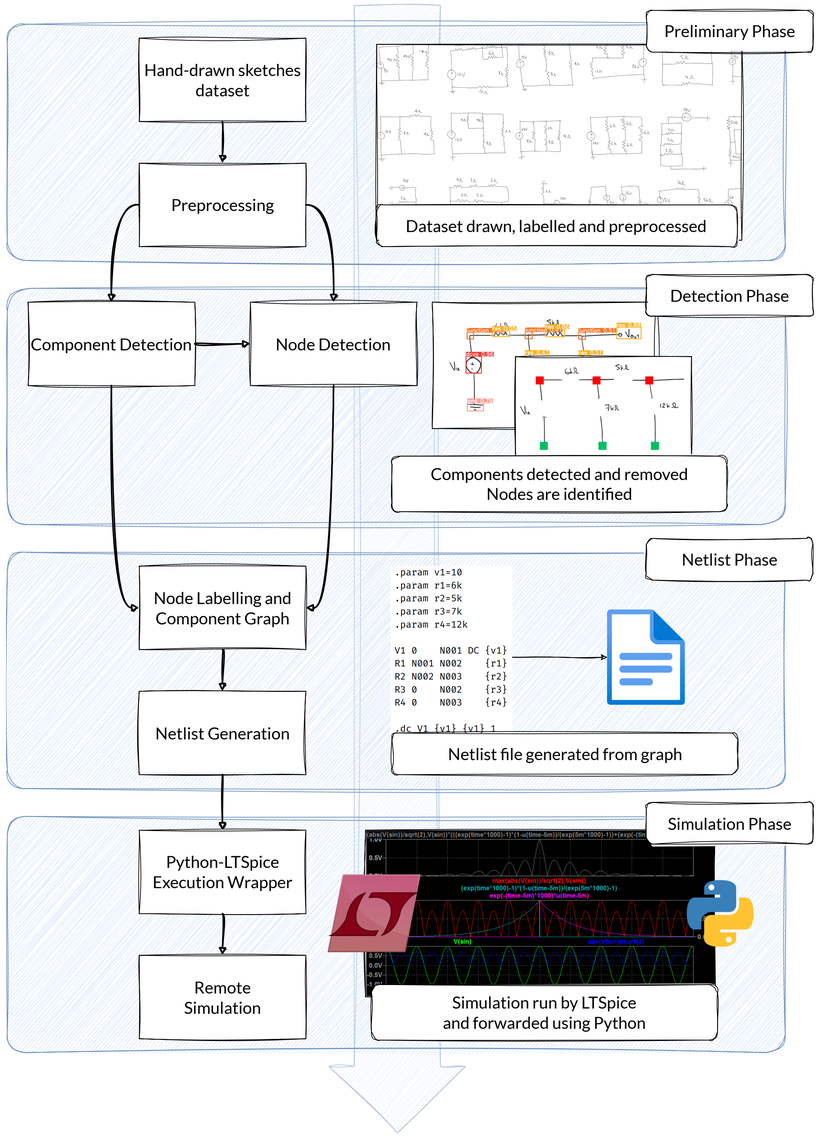

Figure 1. Circuit sketch recognition method and simulation pipeline

5. Method Brief

As outlined in Figure 1, the hand-drawn schematics are preprocessed and then passed to the deep learning object detection algorithm to detect the components of the circuit. The output of the detector is then passed to a post-processing stage to extract the netlist from the detected components. The netlist is then passed to Python and LT-SPICE to generate and run a simulation file.

Class	Precision	Recall	mAP@0.5
Resistor	0.995	1.000	0.995
DC Voltage Source	0.989	1.000	0.993
Ground	0.961	1.000	0.994
Overall	0.982	1.000	0.994

(a) Accuracy metrics for each class

	Class	Actual			
		Resistor	**DC Voltage Source**	**Ground**	**Not Data**
Predicted	**Resistor**	1.00	0.00	0.00	0.09
	DC Voltage Source	0.00	1.00	0.00	0.73
	Ground	0.00	0.00	1.00	0.18
	Missed Data	0.00	0.00	0.00	0.00

(b) Confusion matrix

Table 1. Evaluation metrics of the trained model

6. Findings, Ongoing and Future Work

A hand-drawn dataset of 100 images was created and used to train the model. Each image contained 3 component classes $\{res, dcvs, gnd\}$. Tables 1a and 1b show the model achieves a precision and recall of over 98% for $\{res, dcvs\}$, and 96% for $\{gnd\}$. The confusion matrix reflects this, showing that the model accurately predicts all classes 100% of the time.

The trained detector can also function with reasonable accuracy directly on CAD images. This is demonstrated in a video linked as a **QR code at the end of this poster**.

- **Ongoing Work:**
  - Interpret the circuit diagram and produce a simulation file.
  - Run the simulation using a Python interface to LT-SPICE.
  - Implement the user interface.
- **Future Work:**
  - Increase the set of detectable components such as amplifiers and transistors.
  - Detect text labels to avoid false positive detections.
  - Integrate optical character recognition (OCR) to automate the netlist phase.

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