A.I. POWERED WEB APPLICATION

FOR ELECTRONIC COMPONENTS SELECTION

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IN

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SUBMITTED BY

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DECLARATION

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I wish him success in all his future endeavours.

(Mr. Puneet Bansal)
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Dept. of ECE.
UIET KU

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ABSTRACT

The aim of this project is to develop an artificial intelligence-based web application for electronic component selection by using computer vision. We built a tool that can help the beginners as well as the experts, in component selection, filtering and purchasing. Firstly, you input the required circuit prompt and it detects the basic components using our CNN model. Secondly, with the component's specification used in that circuit, the web app gives you a selection of components available on the leading online marketplace along with datasheet. The objective of our project is to simplify and fasten the existing selection process that may differ depending upon the industry, use case and people involved.

CONTENTS

Introduction

The rise in semi-conductor demand is projected to be $300 billion dollars during 2021-2026 only in India alone. This calls for more research and development maybe specific to the demand or new efficient components, resulting into addition of new products in the market. Keeping a track of more than 5000+ components and their use case is difficult even for a novice. The component selection is a tedious and time-consuming task. In large scale application this process can take more than a couple of months for a VLSI or ULSI task.

On a more basic level, the user is often required to study through a lot of electronics literature before actually building the required circuit and characterise the needs accordingly. Even a simple SMPS circuit can have 100+ combination of components that vary from input and output requirements.

The objective of our project is to simplify and fasten the existing selection process that may differ depending upon the industry, use case and people building the circuit. The first step in the selection process is deciding the input and output requirements. The next step is building an efficient and optimal circuit around the requirements. This step usually includes the component selection process.
Now the question comes, “which all parameters to consider? “.

The quickest and easiest bet is selecting components from a **previous proven design**. But this approach has one **drawback**. If you stick on to an older proven electronic component, you may miss the advantage of a new part, which may bring in benefits like more compact, more integration, more power efficient, better protection, better longevity. When starting a new design, it also brings an opportunity to try newer parts available. New parts need application understanding and many times the application circuit’s complexity drives the part selection. If say part A has complex application circuit w.r.t part B, provided all requirements are met by both, the obvious choice would be to go with part B. But sometimes that comes with a cost, for example, easy application circuit but at a little extra cost, here comes the trade-off.

Electrical parameters like voltage, current, power, accuracy, response time, speed, resolution are the driving factors in component selection. Similarly **Mechanical parameters** like dimension, package and weight is considered in accordance of electrical parameters. Then comes the **Environmental parameters,** they should be known beforehand and be considered carefully. You should know the range of temperate your product will see, then take the worst-case analysis and do the selection, likewise for other parameters. Check properly the operating/storage temperature, humidity, pressure, vibration range and its effect on the part performance. Missing this consideration may lead to field surprises like field failures or bad performance.

Last but not least is **Cost and Availability.** Everyone wants to have the best electronic component at the most affordable cost. Don’t compromise on quality if you are getting at a lower cost. Sometimes device cost more due to better performance, more power efficient, smaller package, more integration, better reliability. So, consider overall value-add rather than just the cost of an electronic component.

Artificial intelligence/machine learning (AI/ML) has the potential to generate huge business value for semiconductor companies at every step of their operations, from research and chip design to production through sales. But recent surveys of semiconductor-device makers shows that only about 30 percent of respondents stated that they are already generating value through AI/ML.

Because of their high capital requirements, semiconductor companies operate in a winner-takes-most or winner-takes-all environment. Consequently, they have persistently attempted to shorten product life cycles and aggressively pursue innovation to introduce products more quickly and stay competitive. But the stakes are getting increasingly high. With each new technology node, expenses rise because research and design investments, as well as capital expenditures for production equipment, increase drastically as structures get smaller. For example, research and design costs for the development of a chip increased from about $28 million at the 65 nanometre (nm) node to about $540 million at the leading-edge 5 nm node. Meanwhile, fab construction costs for the same nodes increased from $400 million to $5.4 billion.

With our tool, we can help the beginners as well as the experts, in component selection, filtering and purchasing. Firstly, you input the required circuit prompt and it detects the basic components using our CNN model. Secondly, with the component's specification used in that circuit, the web app gives you a selection of components available on the leading online marketplace along with datasheet. The objective of our project is to simplify and fasten the existing selection process that may differ depending upon the industry, use case and people involved.

LITERATURE REVIEW

Our project was built using many technologies around. Here we talk about some of the important ones.

1. Computer vision

The heart of our project **computer vision**, is a field of **artificial intelligence** (AI) that enables computers and systems to derive meaningful information from digital images, videos and other visual inputs — and take actions or make recommendations based on that information. If AI enables computers to think, computer vision enables them to see, observe and understand.

Computer vision works much the same as human vision, except humans have a head start. Human sight has the advantage of lifetimes of context to train how to tell objects apart, how far away they are, whether they are moving and whether there is something wrong in an image.

Computer vision trains machines to perform these functions, but it has to do it in much less time with cameras, data and algorithms rather than retinas, optic nerves and a visual cortex. Because a system trained to inspect products or watch a production asset can analyse thousands of products or processes a minute, noticing imperceptible defects or issues, it can quickly surpass human capabilities.

How does computer vision work?

Computer vision needs lots of data. It runs analyses of data over and over until it discerns distinctions and ultimately recognize images. For example, to train a computer to recognize automobile tires, it needs to be fed vast quantities of tire images and tire-related items to learn the differences and recognize a tire, especially one with no defects.

Two essential technologies are used to accomplish this: a type of machine learning called deep learning and a convolutional neural network (CNN).

Machine learning uses algorithmic models that enable a computer to teach itself about the context of visual data. If enough data is fed through the model, the computer will “look” at the data and teach itself to tell one image from another. Algorithms enable the machine to learn by itself, rather than someone programming it to recognize an image.

A CNN helps a machine learning or deep learning model “look” by breaking images down into pixels that are given tags or labels. It uses the labels to perform convolutions (a mathematical operation on two functions to produce a third function) and makes predictions about what it is “seeing.” The neural network runs convolutions and checks the accuracy of its predictions in a series of iterations until the predictions start to come true. It is then recognizing or seeing images in a way similar to humans.

Much like a human making out an image at a distance, a CNN first discerns hard edges and simple shapes, then fills in information as it runs iterations of its predictions. A CNN is used to understand single images. A recurrent neural network (RNN) is used in a similar way for video applications to help computers understand how pictures in a series of frames are related to one another.

The history of computer vision

Scientists and engineers have been trying to develop ways for machines to see and understand visual data for about 60 years. Experimentation began in 1959 when neurophysiologists showed a cat an array of images, attempting to correlate a response in its brain. They discovered that it responded first to hard edges or lines, and scientifically, this meant that image processing starts with simple shapes like straight edges.

At about the same time, the first computer image scanning technology was developed, enabling computers to digitize and acquire images. Another milestone was reached in 1963 when computers were able to transform two-dimensional images into three-dimensional forms. In the 1960s, AI emerged as an academic field of study, and it also marked the beginning of the AI quest to solve the human vision problem.

1974 saw the introduction of optical character recognition (OCR) technology, which could recognize text printed in any font or typeface. Similarly, intelligent character recognition (ICR) could decipher hand-written text using neural networks. Since then, OCR and ICR have found their way into document and invoice processing, vehicle plate recognition, mobile payments, machine translation and other common applications.

In 1982, neuroscientist David Marr established that vision works hierarchically and introduced algorithms for machines to detect edges, corners, curves and similar basic shapes. Concurrently, computer scientist Kunihiko Fukushima developed a network of cells that could recognize patterns. The network, called the Neocognitron, included convolutional layers in a neural network.

By 2000, the focus of study was on object recognition, and by 2001, the first real-time face recognition applications appeared. Standardization of how visual data sets are tagged and annotated emerged through the 2000s. In 2010, the ImageNet data set became available. It contained millions of tagged images across a thousand object classes and provides a foundation for CNNs and deep learning models used today. In 2012, a team from the University of Toronto entered a CNN into an image recognition contest. The model, called AlexNet, significantly reduced the error rate for image recognition. After this breakthrough, error rates have fallen to just a few percent.

Computer vision applications

There is a lot of research being done in the computer vision field, but it’s not just research. Real-world applications demonstrate how important computer vision is to endeavours in business, entertainment, transportation, healthcare and everyday life. A key driver for the growth of these applications is the flood of visual information flowing from smartphones, security systems, traffic cameras and other visually instrumented devices. This data could play a major role in operations across industries, but today goes unused.

2. Convolutional Neural Network

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm that can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image, and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets have the ability to learn these filters/characteristics.

The architecture of a ConvNet is analogous to that of the connectivity pattern of Neurons in the Human Brain and was inspired by the organization of the Visual Cortex. Individual neurons respond to stimuli only in a restricted region of the visual field known as the Receptive Field. A collection of such fields overlaps to cover the entire visual area.

A CNN model includes following layer:

a) Input Layer

The Input Layer serves as a buffer for the input before it is sent on to the following layer.

b) Convolutional Layer

The main operation of feature extraction is performed by the Convolution Layer. It uses the supplied data to conduct a Convolution process. Sliding the kernel across the input and performing the sum of the product at each position is how the convolution process is carried out. Stride is the size of the step in which the kernel slides. The number of feature maps created in a convolutional layer is also known as the depth of the layer. Several convolutional operations are done on the input using various kernels, resulting in distinct feature maps.

c) Rectified Linear Unit (ReLU)

It is an activation function that is used to inject nonlinearity into a system. Negative values are replaced with zero, which speeds up the learning process. Every convolution layer's output is routed via the activation function.

d) Pooling Layer

Pooling employs a sliding window that moves in sync with the feature map, converting it into representative values. It also minimizes the spatial size of each feature map, which reduces the network's computation. The terms "minimum pooling," "average pooling," and "max pooling" are often used.

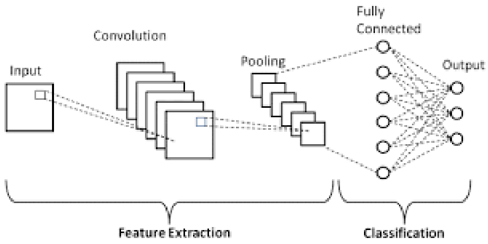


Fig. A CNN model

The data is then fed into the model and output from each layer is obtained this step is called feedforward, we then calculate the error using an error function, some common error functions are cross-entropy, square loss error, etc. After that, we backpropagate into the model by calculating the derivatives. This step is called Backpropagation which basically is used to minimize the loss.

3. Electronic components

An **electronic component** is any basic **discrete device** or physical entity in an electronic system used to affect electrons or their associate fields. Electronic components are mostly industrial products, available in a singular form and are not to be confused with electrical elements, which are conceptual abstractions representing idealized electronic components and elements.

Electronic components have a number of electrical terminals or leads. These leads connect to other electrical components, often over wire, to create an electronic circuit with a particular function (for example an amplifier, radio receivers, or oscillators). Basic electronic components may be packaged discretely, as arrays or networks of like components, or integrated inside of packages such as semiconductors integrated circuits, hybrid integrated circuits, or thick film devices. The following list of electronic components focuses on the discrete version of these components, treating such packages as components in their own right.

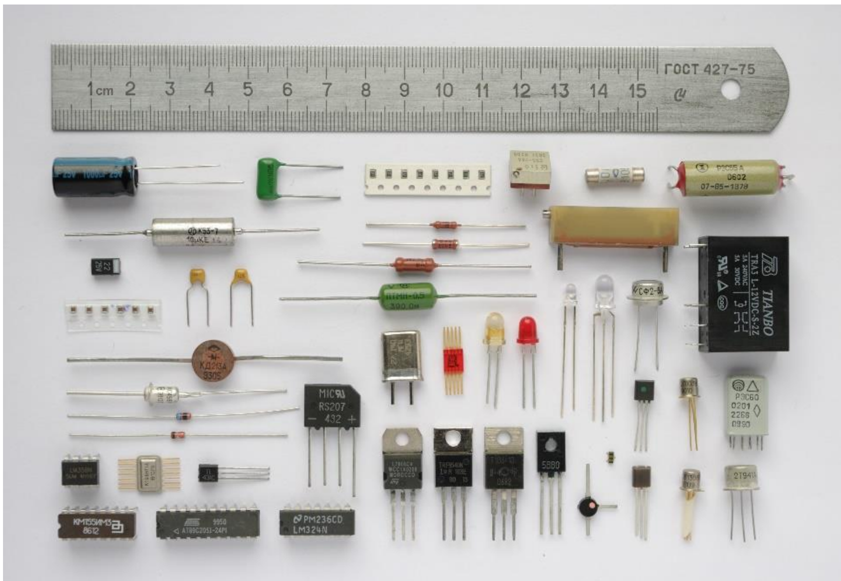


Fig. Various electronic components

Classification

Components can be classified as passive, active, or electromechanic. The strict physics definition treats passive components as ones that cannot supply energy themselves, whereas a battery would be seen as an active component since it truly acts as a source of energy.

However, electronic engineers who perform circuit analysis use a more restrictive definition of passivity. When only concerned with the energy of signals, it is convenient to ignore the so-called DC circuit and pretend that the power supplying components such as transistors or integrated circuits is absent (as if each such component had its own battery built in), though it may in reality be supplied by the DC circuit. Then, the analysis only concerns the AC circuit, an abstraction that ignores DC voltages and currents (and the power associated with them) present in the real-life circuit. This fiction, for instance, lets us view an oscillator as "producing energy" even though in reality the oscillator consumes even more energy from a DC power supply, which we have chosen to ignore. Under that restriction, we define the terms as used in circuit analysis as:

a. **Active components** rely on a source of energy (usually from the DC circuit, which we have chosen to ignore) and usually can inject power into a circuit, though this is not part of the definition. Active components include amplifying components such as transistors, triode vacuum tubes (valves), and tunnel diodes.

b. **Passive components** cannot introduce net energy into the circuit. They also cannot rely on a source of power, except for what is available from the (AC) circuit they are connected to. As a consequence, they cannot amplify (increase the power of a signal), although they may increase a voltage or current (such as is done by a transformer or resonant circuit). Passive components include two-terminal components such as resistors, capacitors, inductors, and transformers.

c. **Electromechanical components** can carry out electrical operations by using moving parts or by using electrical connections.

On a circuit diagram, electronic devices are represented by conventional symbols. Reference designators are applied to the symbols to identify the components.

Most passive components with more than two terminals can be described in terms of two-port parameters that satisfy the principle of reciprocity—though there are rare exceptions. In contrast, active components (with more than two terminals) generally lack that property.

4. Component Selection

Here we talk about traditional electronic component selection guidelines. Poor component selection can lead to many problems within our electronic design, PCB layout, schedule, etc. Luckily, there are many ways to choose parts that will deliver projects on time and produce functional boards, leaving both you and your clients happy.

The most important step in part selection is design requirements. The real problem we're solving isn't which parts to choose, but which parameters and functions we need to satisfy the project needs—parts just help achieve those needs.

How to select electronic components?

The following guidelines will help to find and select the ideal electronic components/devices for any project.

1. **A clear, functional block diagram is essential**

A picture is worth a thousand words; a functional block diagram is worth ten thousand. An accurate depiction of the system is essential to understand the problems we are solving and is achieved with the functional block diagram. Nothing describes an electrical problem better than a system block diagram. System block diagrams allow us to see how things are connected as well as what functions, features, and objects affect one another and why. Once we meet the needs of those function blocks, we meet the needs of the system.

2. **Circuits must meet required functionality**

Now that we have a functional block diagram and function blocks, we dig deeper. We must create the circuit topologies that perform the functions in those function blocks.

For instance, let's say we need a function block to change a 12 V input to a 24 V output. With our engineering knowledge and expertise, we know a boost converter is needed to perform that function.

Sometimes additional resources can be used to aid in the creation of these circuit topologies. I recommend reading application notes and reference designs for projects similar to yours. They can act as cheat sheets to find the types of circuits you need to meet a system block's required functionality.

3. **Find parts that fit into the circuit topology and parameters**

We need to find parts that meet our circuit requirements (topology, operating voltage, and current). Electronic devices are rated for specific parameters, such as voltage, current, bandwidth, temperature, etc. These part selection requirements come from the circuit topology. Once we know the types of components that will meet our topological, voltage and current needs, we need to go shopping for those components.

4. **Trusted Suppliers are Key**

Time to market is very important for many hardware designers, so we need our parts to show up on time to meet project deadlines. To achieve this, we work with reliable part vendors. It's even better when those vendors help us boost our efficiency in selecting and ordering those parts through a good online bill of materials tool, great customer service, and good shipping practices. Some of the best examples in the USA are Digi-Key, Mouser (in Texas), Newark, Element 14, just to name a few.

5. Keep Electrical and Physical Criteria in Mind

Now that we have determined design requirements and part vendor, we need to find components. When searching, enter the electrical and physical criteria we need to get a specific function/task handle.

6. Pay Attention to Part Availability

Lead times and unavailable parts are currently at an all-time high. Before deciding on a part, make sure it is currently available or the lead time fits within the design schedule.

7. **Choose Newer Parts**

Whenever I work with pre-existing designs, there is at least one part that has a superior version of itself or has become obsolete. Unless a specific version of a part is needed, it's important to take advantage of newer parts that can act as direct substitutes for the older device. The newer parts tend to be more reliable, cost the same or less, are easier to find, and in stock.

8. **Match Parts to Meet PCB Environmental Class Requirements**

Designs are typically spec'd out to work in certain temperatures, environments, and so on. Luckily, we don't have to guess at this. PCBs are categorized by specific classes and categories. Based on IPC standards IPC-7351B, IPC-CM-770E, and IPC-D-330, specific class ratings are given to circuit boards depending on their performance and materials.

- Class 1 - General Electronic Products that have a short life span. For example, some inexpensive toasters, small toys, and generally cheaper electronics.
- Class 2 - Dedicated-Service Electronic Products that are serviceable and repairable for a reasonable lifetime. Some examples are commercial communications devices, air conditioners, and laptops.
- Class 3 - High-Reliability Electronic Products that need to be very reliable in many different environments and have a very low failure rate. Examples of this class would be medical equipment and military weapons.
- Class 3/A - Military and/or space avionics circuits.

To meet the environmental and performance requirements of your product, it is essential to choose parts to match the class of the board (operational temperature, medical grade, etc.).

9. **Consider Price**

The first major limiting factor in earning money is time. How long will the product take to make? The second, more important, factor is money. How much will it cost to make it? Cost is extremely important in business because it cannot survive if mass producing a product always loses money.

The cost of an electronic part goes up the harder it is to manufacture; therefore, traits such as precision of value or measurement will greatly affect part price.

- Current and Voltage range (larger range = more expensive)
- Operating Temperature (higher temperature tolerance = more expensive)
- Voltage isolation - (higher blocking voltage = more expensive)

In the end, consider the price and cost of every component in your circuit and go with the lowest priced parts that also adhere to design requirements.

DATASET PREPRATION

After much discussion and thinking, we ended with 9 classes to target primarily for recognition task:

1. Capacitor
2. Diodes
3. Inductor
4. LED
5. Op-Amp
6. Resistor
7. Switch
8. Transformer
9. Transistor

We were unable to find any dataset online so we ended up building our own dataset of total 200 images with almost 20 images of each class which were enough to extract major features from the component image.

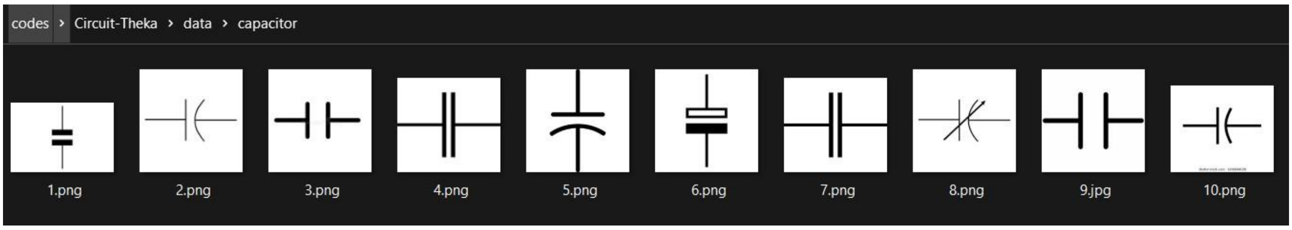


Fig. Example capacitor images

Data is the heart and soul for an AI project. With time and more data, we can build a stronger AI to detect components and provide a robust facility to the user. This can be done by more traffic on our web application which will happen over time.

CNN MODEL AND EVALUATION

Our next task in line was to build a convolutional neural network that can recognise the components in a circuit image. This was archived with great accuracy of 95% and is working fine enough for our initial recognition task.

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_2 (Conv2D)            (None, 24, 24, 72)        1872
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 12, 12, 72)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 10, 10, 36)        23364
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 5, 5, 36)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 5, 5, 36)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 900)               0
_________________________________________________________________
dense_2 (Dense)              (None, 81)                72981
_________________________________________________________________
dense_3 (Dense)              (None, 9)                 738
=================================================================
Total params: 98,955
Trainable params: 98,955
Non-trainable params: 0
_________________________________________________________________
None
```

Fig. Architecture of the CNN model

```
history=model.fit(X_train, y_train, epochs=10, batch_size=5,shuffle=True,verbose=1)

Epoch 1/10
14/14 [==============================] - 0s 6ms/step - loss: 25.7263 - accuracy: 0.1343
Epoch 2/10
14/14 [==============================] - 0s 6ms/step - loss: 4.6483 - accuracy: 0.3881
Epoch 3/10
14/14 [==============================] - 0s 6ms/step - loss: 1.5443 - accuracy: 0.6269
Epoch 4/10
14/14 [==============================] - 0s 6ms/step - loss: 0.7580 - accuracy: 0.7612
Epoch 5/10
14/14 [==============================] - 0s 6ms/step - loss: 0.5468 - accuracy: 0.8358
Epoch 6/10
14/14 [==============================] - 0s 5ms/step - loss: 0.3308 - accuracy: 0.8806
Epoch 7/10
14/14 [==============================] - 0s 6ms/step - loss: 0.1280 - accuracy: 0.9403
Epoch 8/10
14/14 [==============================] - 0s 6ms/step - loss: 0.1058 - accuracy: 0.9701
Epoch 9/10
14/14 [==============================] - 0s 6ms/step - loss: 0.1159 - accuracy: 0.9552
Epoch 10/10
14/14 [==============================] - 0s 6ms/step - loss: 0.0969 - accuracy: 0.9552
```

Fig. Training the CNN model

Generally, the electronic components symbols are made of few straight lines and some occasional curves around. This made easier for our CNN to detect components in a schematic.

The output of our CNN is a list of components that are detected in the schematic. This list of components can be used further to find the specification of components according to the user’s need.

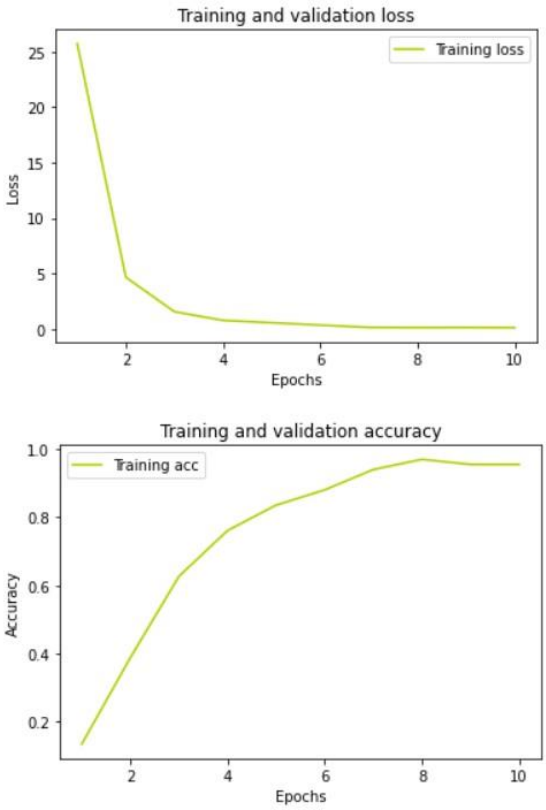
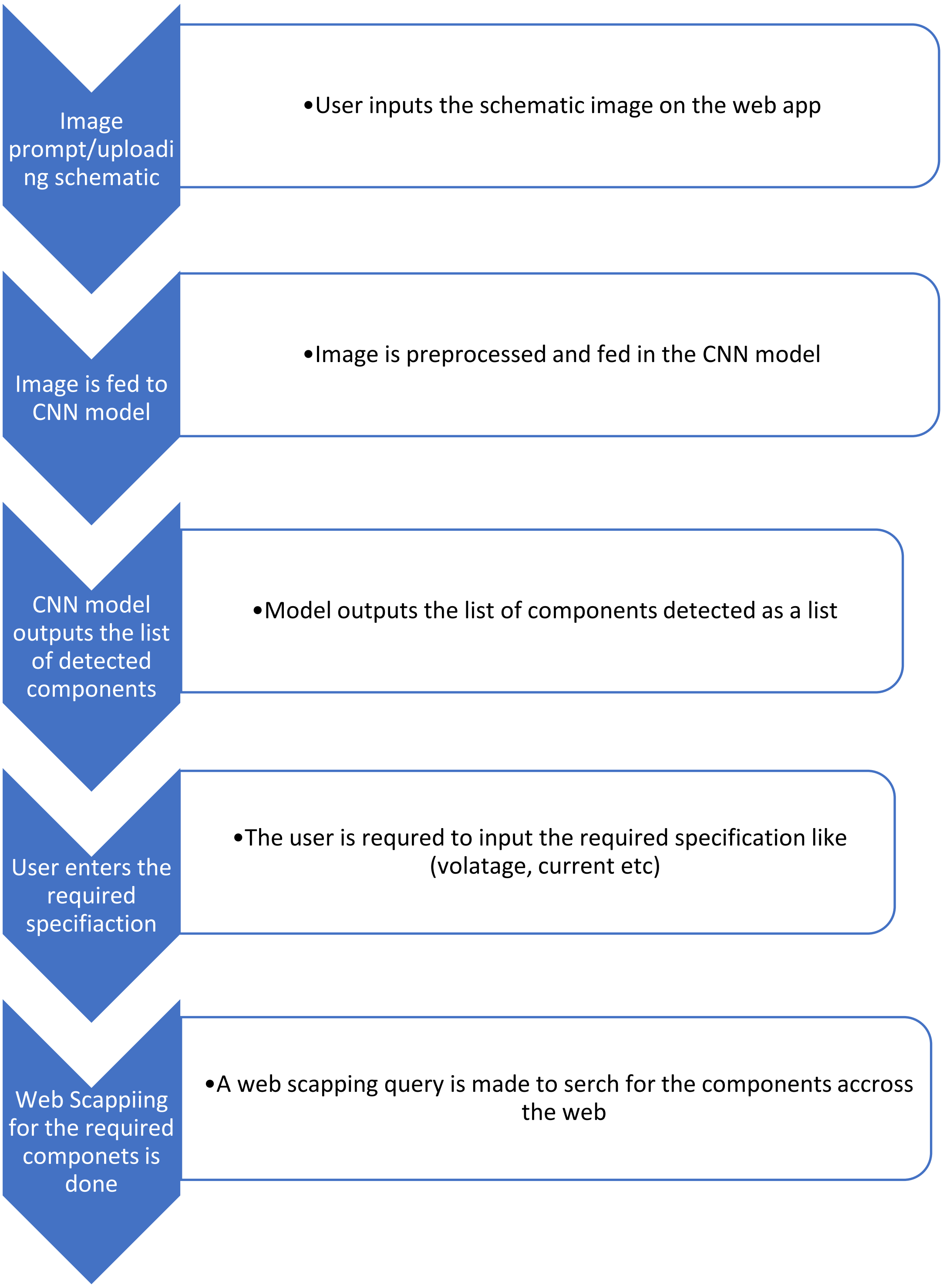


Fig. Training Accuracy vs Losses

We got an accuracy of 95% on our dataset and we saw losses less than 5% over multiple epochs. We can even fine tune our aur settings with time and knowledge about the hyperparameters to get even better results but for the initial recognition task, these work efficiently.

PROJECT FLOW



RESULT

After a tedious process of making everything work together, we completed the website how we desired it to be. It is still in very initial process and our current goal is to identify small 3-30 component schematic.

We call it **Electronic Eye,** here's the front page of our website.

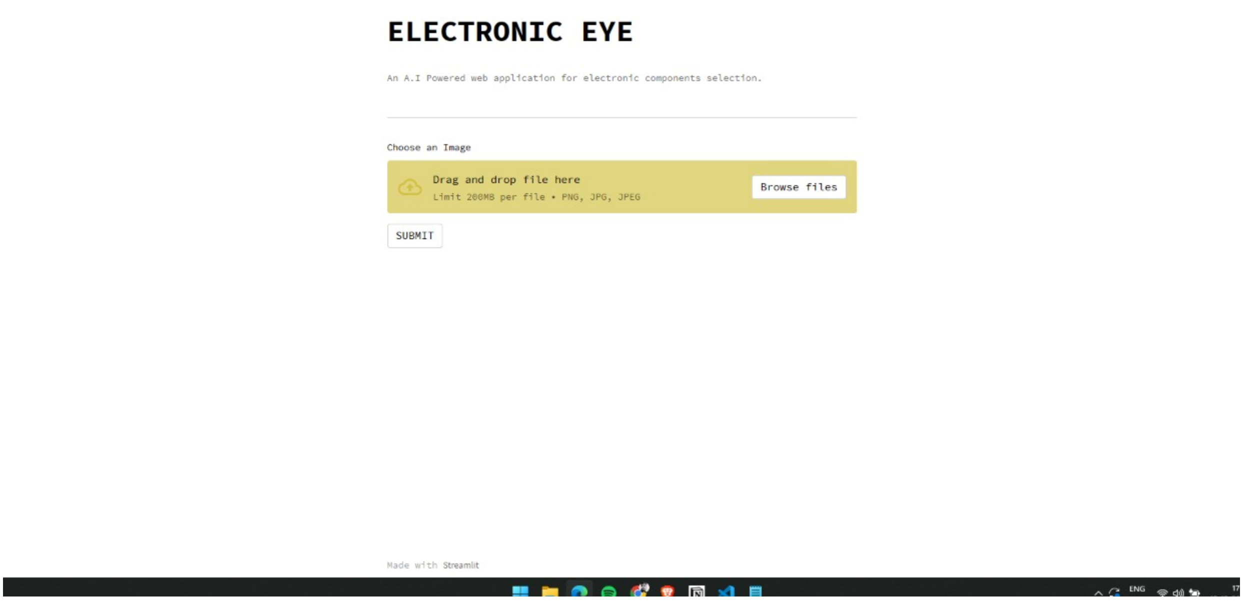
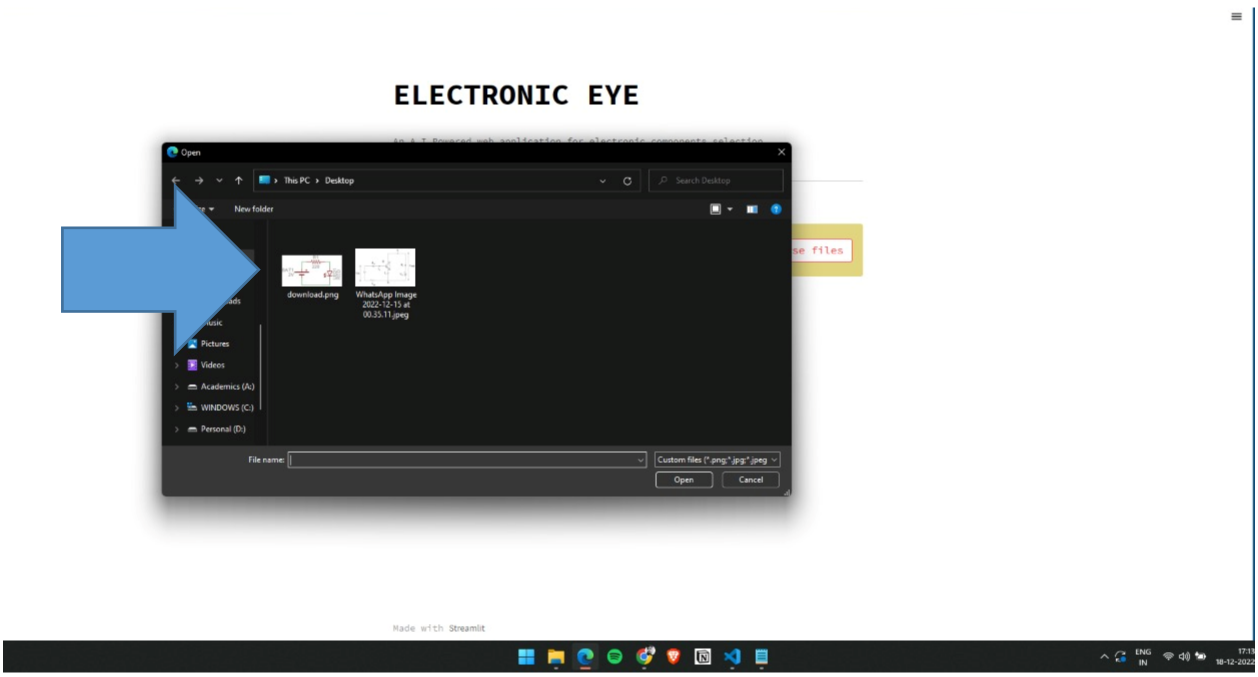


Fig. Front page of the website

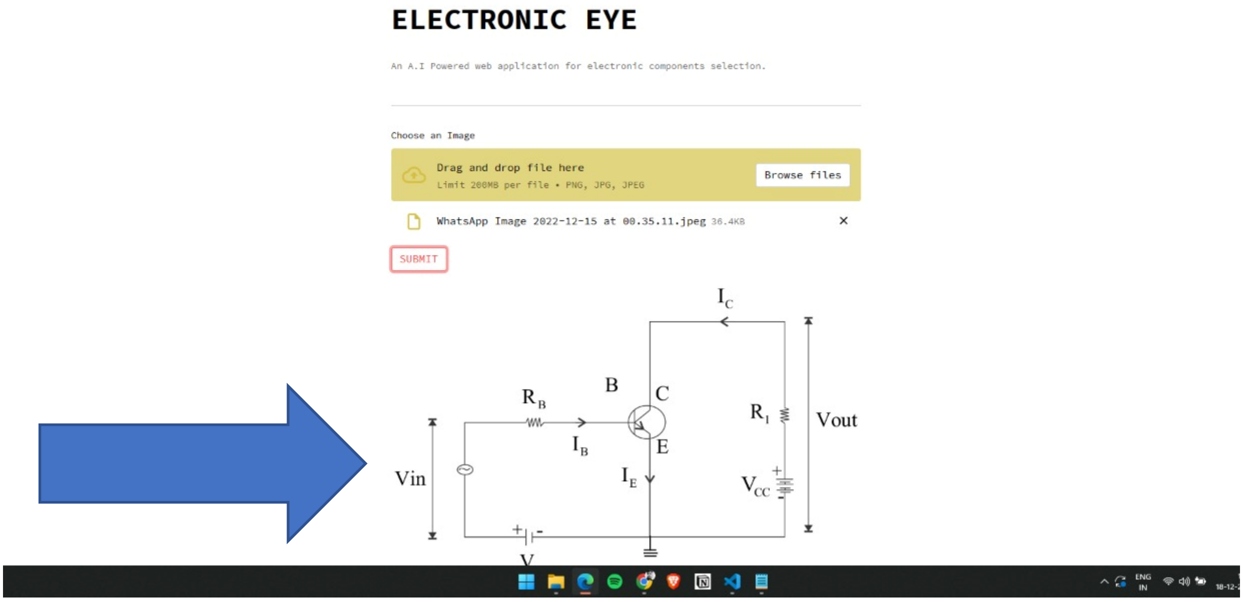
Tour of our website and it's functionalities:

1.



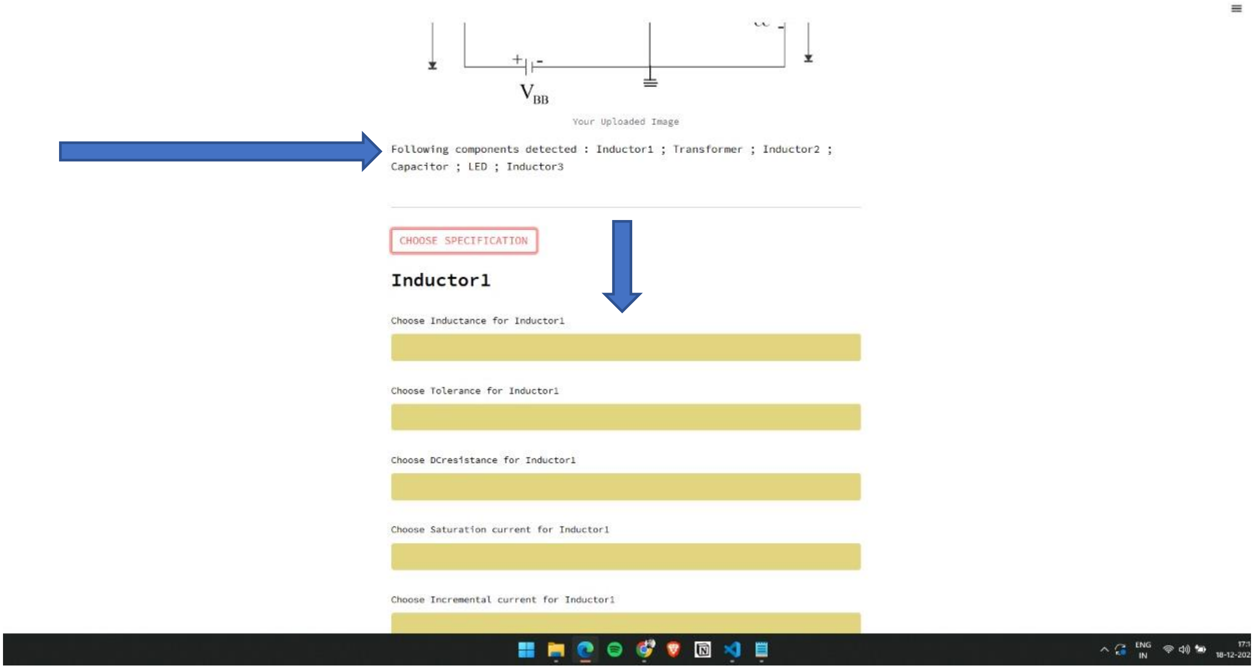
After clicking the submit button, you can choose and upload your schematic to the website.

2.



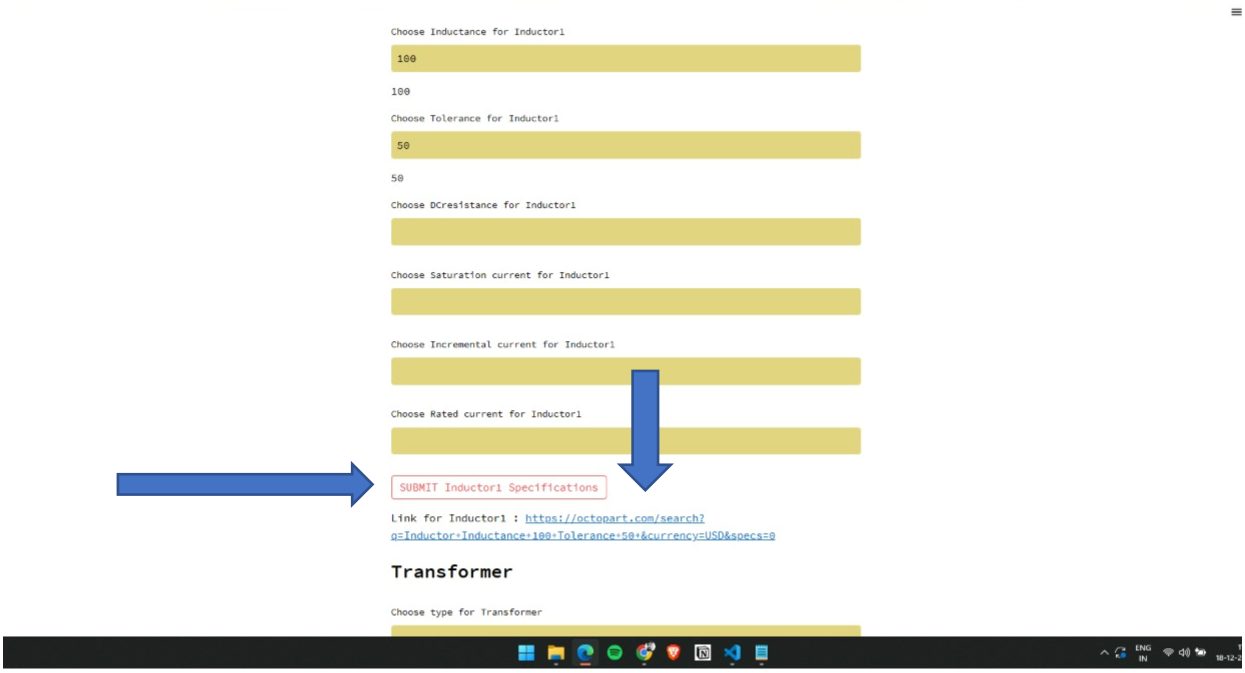
After, submitting the schematic, the image will be uploaded to the website as you can see above.

3.



After uploading the image, you can see, that our AI model detected the components in the image. It detects the components present and it let’s the user enter the requirements of each component.

4.



The user can then enter the requirements and submit it. This gives back the user a link through which they can look for the parts available according to their requirements and the complete datasheet and pricing.

CONCLUSION

Our CNN model had some inaccuracy while working on a electronic schematic since we trained it on individual component image but it was for a good start. We will be training and fine tuning the hyperparameters in our model for even more accuracy while working with electronic schematics since that is our end goal.

It was a great learning opportunity, full with ups and downs. Artificial Intelligence is marked for the future and we are thrilled to implement it with our areas of interest which is electronics and communication. This project helped us to understand the problems faced by industry professionals and even by beginners and with this project we aim to simplify the component selection process.