Exploring the Impact of Neuromarketing to Promote Product Value using EEG Signals

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A thesis submitted to the Department of Computer Science and Engineering
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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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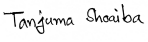

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Ethics Statement

We hereby declare that this document withholds our own sole work derived from the collective incessant hardwork for the past three semesters and the knowledge we have been fortunate to have gathered over the years.

Abstract

Neuromarketing is applying neuropsychology in marketing research which studies consumer sensory-motor such as cognitive and affective response to marketing stimuli with the help of modern technologies.The use of medical technologies to study the brain's responses to understand the decisions of the consumers is neuro-marketing. This is a relatively new but rapidly emerging field as it has the potential to predict consumer behaviors. Several tools exist that aid neuro-marketing such as EEG, FMRI, MEG etc. The use of these technologies was strictly limited to medical purposes until most recently. These technologies are now being used to study brain signals of consumers to take a deep dive into the consumer's mind and develop marketing strategies that will be most effective. We believe that neuropsychological measures soon will be widely acknowledged and used as a complimentary method in classical marketing research. We tried to contribute to this field by doing as much as we could with our work.

Keywords: Neuro-marketing, Electroencephalography(EEG), Consumer Neuroscience, Consumer Behaviour, Functional Magnetic Resonance Imaging(FMRI), Magnetoencephalography(MEG).

Dedication

Dedicated to our beloved parents and our respected faculties and the dedicated souls in the field of Computer Science and Engineering.

Acknowledgement

Firstly, all praise to the Great Allah for whom our thesis have been completed without any major interruption. Secondly, to our advisor Dr. Mohammad Zavid Parvez Sir for his kind support and advice in our work. He helped us whenever we needed help.
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Chapter 1

Introduction

1.1 Thoughts leading to Neuromarketing

Neuromaketing combines neuroscience, marketing and psychology. It studies our buying decisions and how our emotions influence them without us even knowing. To be more precise, it studies the brain's response using medical technologies to marketing stimuli [4]. The goal is to study how the brain is physiologically affected by advertising and marketing strategies. In order to analyze these strategies, brain activity is monitored and measured using neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). Researchers and marketers delve into the derived information to decipher what probes consumers to make a purchase and what parts of the brain influenced them to reach that conclusion. Research over the past few years has confirmed that 95 % of our decisions are made subconciously [22]. Each year, over 400 billion dollars is invested in advertising campaigns [10]. But 100 billion of it goes to waste.At the same time, medical studies have shown that we simply cannot make a decision devoid of our emotions. The main reason is traditional marketing fails to pay attention to consumers subconcious thoughts. Consumers were found to have made decisions in split seconds at times, according to further studies. That is why many questionnaire, attitude or verbal communication, focus group assessments fall short miserably as consumers themselves could not articulate why they made certain decisions or being confused simply made up a lie. For which it is an absolute must to get to know what went through their brains while making that split second cut for a product. Neuromarketing sheds light on the consumer's subconcious thoughts, making it possible to know their decision process, what they are thinking willingly and subconciously [11]. The neuromarketing premise is simple: consumers can lie; statistics don't. Neuromarketing has ever expanding impacts as it provides us with the best tools that can be used to speak to the subconscious. Therefore it is possible to utilize this to influence consumers. Also, it provides an insight to improve the design of products before the actual launch in the market [32]. Over the last 20 years, growing research from Neuroscience, Social Psychology and Behavioral Economics has been providing new insights on how the brain makes buying decisions. Thoughts, feelings and memories can subconciously change our experience with a product. This is how advertisements, campaigns compel the consumer to act accordingly in purchasing a certain product or drive away competition. Neuromarketing research is conducted by recording and analyzing certain bio-metrics features such

as Electroencephalography (EEG), Facial Coding, Facial Expression Recognition, Gesture Pattern Recognition, Eye Tracking, Galvanic skin response and electrodermal activity. It is possible for marketers to create a more effective and engaging marketing strategy with the help of Neuromarketing. Understanding consumers viewpoints, behavior, action, emotion and non-conscious insights, feeling measurement and priming effects will help the marketers to plan and develop marketing strategies accordingly [29]. Not only the brand will be benefited by Neuromarketing, but also the general people who are exposed to hundreds maybe thousands of ads everyday. Through creating more informative, emotionally rewarding, and useful ads it is possible to create an enhancing customer's experience with products or brands long before consumer decides to purchase [18] Neuromarketing can also benefit the device manufacturers. Researchers always wanted a mobile biosensor solution which is not intrusive nor intimidating but will provide accurate, clean data for research purpose [19]. Neuromarketing can be the solution to solve that problem and be the bridge between data and researchers. Electroencephalography (EEG) and Functional Magnetic Resonance Imaging (fMRI) are two of those technologies which played a vital role in the field of Neuromarketing research acceleration. As subjects react to vision, taste, smell, sound and obvious signals brains bloodstream is followed and recorded by a ground-breaking magnet in fMRI. fMRI can detect a profound piece of the brain which is known as the "Pleasure center" which indicates how individuals react to the marketing strategy or advertisement. However, the price of fMRI is a thing to worry about as it is not that cheap. Therefore, it can sometimes be a burden for researchers and analysts. The equipment can cost from $150,000 to$ 300,000 or above [37] However, on the other hand, EEG is far less expensive than fMRI. EEG signals can be derived by connecting a cap of electrodes to the sample's scalp where the electrodes can also be moved and placed freely. The electrodes can measure electrical waves that are created by the brain. Through analyzing the brain waves scientists can follow the subject's instinctual motions through their action variance. For instance, outrage, fervor, distress, and desire. However, EEG is unable to access the profound pieces of the brain like fMRI, which is known as the "Pleasure Centre" [26] . In Neuromarketing research EEG continues to be the most popular among many popular measurement technologies and there are many reasons behind it. EEG can measure and capture brainwave activity as the brain processes data. For example, EEG can measure brainwave signals as we perceive visual, auditory, smell, taste and tangible senses also as we process our thoughts. Through the subject's behavior and choices, EEG directly measures its brain activity, rather than indirectly. As technological advancement is occurring EEG equipment is becoming less expensive, portable, and wireless. The affordability and portability are creating new possibilities for studies such as mobile, in-store, and virtual reality. New machine-learning and statistical approaches are being used to understand and decipher the brainwave signals measured by the EEG signal. Analyzing these data has brought up many groundbreaking discoveries that no one would have thought is possible a few years back [43]

1.2 Problem Statement

Existing traditional forms of marketing fail to grasp the entirety of the human mind. Essentially because they leave out taking the subconcious mind and emotional expe-

riences into account. Over the past 100 years, advertising agencies have been trying new ways to sell [2]. Every year 9 out of 10 products fail and around a 100 million dollar are wasted on marketing. If we manage to drive away mindless marketing, we can stop wasting time and money spent behind them ultimately summoning a win-win for both businesses and consumers. Neuromarketing can help generate better and improved customer experiences. If we can pinpoint what makes the brain click we can apply that knowledge and tinker products and services to maximize consumer satisfaction that transfers into a stronger bottom line. Furthermore, neuromarketing makes us realise most of what controls our decisions are invisible to the naked eye. If we can analyse and tap into which parts of the brain impacts drawing conclusion regarding purchasing, we can attain a marketing game changer and not only keep the development of marketing ongoing but skyrocket it [8] . What is most fascinating about this game changer and the findings of neuromarketing is that most of the times the very things that drive our choices are those invisible to the naked eye [50].
Previously carried out consumer research data can be misleading with false and made-up information [25]. Making them less effective and dependable. The root cause being consumers not knowing themselves as much as they think they do. Perplexed with their thought process they simply guess the means that lead them to buy something.
Through measuring and analyzing the EEG signal it is possible to determine what someone is thinking. That is where neuropsychology comes into play. By observing neuropsychology patterns individuals- actions, behaviors, quirks can be understood and their preferences or what triggers their satisfaction can be boiled down. Using this tactics, products and services can both be developed and customised to their preferences. Developing marketing strategies and campaigns that ensures better understanding of the human mind and its needs is a win-win for all. ,patterns recognized by analyzing neuropsychology can help in building Neuromarketing strategies.

1.3 Research Objectives

It has been more or less 10 years Neuromarketing has been around and day by day it is becoming more and more popular. Many big organizations and corporations have adapted this method of marketing for planning, bundling and promoting their product though there are a lot who are skeptical about this approach of marketing. However, this process takes a lot of and is expensive than expected. Therefore, here through our approach, we are trying to find out how neuropsychology might help in the field of marketing with machine learning approach which can deliver more accurate and efficient results in a short span of time. Our objective in this research covers various grounds. Starting from market research, to analyzing customer perception and lastly to create such a system to feel the void of a tool which could let the marketers peek into their customer's mind and predict possible future outcomes, a field that is yet to explode in the current business sector. Our objectives include but not limited to creating a framework that can extract consumers preferences based on their brain signal but also introduce a new method of market research that simultaneously gives information of a marketing strategy's current performance, its selling points, its issues and ways of renovating the strategy in future iterations. Information that the companies will be able to use in more than one way for their

business development. Also, a system that can understand the recent market trends directly through measuring and analyzing consumer's perspectives and points of view.

1.4 Neuromarketing: The Next Big Buzz

Neuromarketing is one of the most prominent fields of studies now-a-days that combines the concepts of psychology and neurosciences and blends them with financial constructs such as marketing and economics. Despite being the control center of our body, the brain is still very much susceptible to marketing and advertising ploys. The primary goal of neuromarketing is to study and understand exactly how our brain reacts to these different marketing strategies and asses the effectiveness of the different ones that are used on a day to day basis. Various advanced techniques such as Functional Magnetic Resonance Imaging (fMRI) and Electroencephalography (EEG) are used to monitor how the brain waves reacts to different types of advertisement. In addition to the brain imaging, other physiological aspects such as eye tracking, heart rate or respiration[28] Throughout these techniques and the usage of Neuromarketing, it is possible to understand the preference of individuals between different products and asses how different factors such as familiarity to the product and branding affects the choice of the consumer. Traditional marketing strategies doesn't really give us enough information or penetration to properly understand if an advert has any sort of impact on consumer's product preference, as we are unable to read through the cognitive state of our test subject. Brand familiarity plays a significant role when in consumer's choice as it is shown to have very deep correlation with neural activity. Author Christopher R Madan et al illustrated in his book that the whole field of Neuromarketing study and research is still at a very juvenile stage and consumer protector groups alongside academics are still approaching the whole concept of this with extreme caution, primarily because of the possibility of being able to create a specific neurological effect on the a consumer and manipulate them at a subconscious level. This could very easily raise some ethical conundrum in the long run [34].

1.5 Neuropsychology: The Science of Brain

Neuroscience has been playing a significant role for more than 10 years in the development of Neuromarketing research for measuring the behavior of consumers alongside analyzing the state of the market. Few notable projects such as The Brain Research Through Advancing Innovating Neurotechnology (BRAIN) initiative and European Union's Human Brain Project are living proof of concepts that are helping neuroscientists fill in the gap between consumer neuroscience research. Even though the above mentioned studies are not directly related to neuromarketing, having a proper understanding of the anatomy of the brain and it's psychological capacities will help neuroscientists all around the world understand how the brain reacts in contrast to different types of consumer behaviors. Making such an assessment is currently impossible with the tools that we have at our disposable, however, the wall between what is possible and what is not is thinning down with each passing day. It won't be long when neuroscientists will be able to seamlessly understand

and infer how the consumer's senses are being used when it comes to choosing a product and acquiring it. Further studies and deeper dives into neurosciences are needed to enhance the depth of knowledge that we have regarding our own psyche if we want to relate it to consumer research. If we want to exactly understand what would be the perfect fragrance to spray at a hall of 30,000 feet to attract mostly senior customers or find our how the mind of a consumer reacts to food when they are being served in an Aircraft, we must learn to understand our brain at a very subliminal level that would allow us to pin-point the exact neurons that light up due to these actions. When it comes to the perspective of the consumer neuroscientists, they also hold a similar opinion that more advancements are required in neuroscience technology in order to improve consumer research. There are a number of different consumer research journals that were able to point out some unique cases of consumer neuroscience.

1.6 Normalising Neuromarketing: Ethics and Morals

Implementing certain ground rules, establishing ethics and morals is crucial when dealing with an exceptionally sensitive information of the brain. The scientists in the filed of neuroscience have thus distinguished it into two collections of issues: (1) the ethical issues and consideration needed to be implied throughout all laying out and executing neuroscientific researches and (2) evaluation of the ethical and social impact which hold results of these test conclusions could have on existing social, moral, and lawful developments and are thus referred to as "ethics of practice" and "ethical implications of neuroscience" .

Before all else, our own set of ethics need to be checked since we are working on neuroscience and promoting product value based on its outcomes. Including thorough clinical related inquery, apt rules for utilizing vertebrate tissues. Besides studying biology, privacy rights, testing for any neurological imbalances. Either ways the ideals sum up to neuroethics.

"Ethical implications of neuroscience" holds the second part, put on a novel pedestal of neuroethics and considered to be an essential moving forward. The idea is to delve into the reasons for the connection of the subconcious mind and society's agendas which will require a concussion of neuroscientific data with the moral and social arrangement. The progress is likely to help minimize imbalances prevailent in the society.

Neuroethics will in all probability generate vivid ranging results. It is necessary to understand that neuromarketing is no way pressing brainswashing or manipulation of the mind [48] Instead it is only helping us yield the preferences our minds, our thoughts naturally generate.Indeed so, seeing that it in this way infringes on the success of the person and our broad open, this is often something be that as it may relate investigation that might also or need to be grasped within the cognitive state. It's exceptionally important that neuroethicists take portion in a really discourse with elegant society. To create this conceivable, in any case, it's basic inside the moment to make advance toward neuroliteracy" of the final populace and so the media. We ought to always enterprise to form the subtleties of neuroscientific counsel with respect to out there to the lay open by means of the media and do without the modern act of supporting it sound bites. For its genuinely with a nuanced comprehension of the science, and stuck up believe in the targets of neuroscientists,

that genuine headway are made on these tough problems. Over the preeminent current few months, we've identified very as of late the essential clamors of this kind of talk. Through neuromarketing, marketers simply continue on doing what they have always done but with a more effective tool, no harming privacy [17].

1.7 Consumer Behavior and Marketing Strategies

Client behavior answers why and how a buyer buys a item or a service. Whereas showcasing procedure is the blend of item, cost, dissemination, and promotion which is fitting for a clump of customers. Understanding the purchaser's behavior and building up an promoting framework fittingly can offer assistance in creating products and wanders with the most excellent benet making potential. So as to do so first client conduct must be caught on back to the front. Steps of the purchaser's decision-making prepare ought to be seen totally. The buyer decision-making process, for the foremost portion, comprises of require affirmation, information look, assessment, buying choice and post buying behavior [42]
Understanding the buyer's requirements and their securing strategy criteria, the showcase is isolated into different social occasions. Uncommon and particular promoting techniques are made for each part. There are various components behind the purchaser's essential authority. Among those impacts could be a key calculate. A client can be affected inside fair as can be remotely influenced. Circumstance moreover impacts a consumer's decision-making preparation. It is the essence of marketing tactics to bring in consumers and have them buy particular goods [9]. Enabling the mass media and public to neuroliterature is another way of easing the tension and anxiety regarding this bubble [1].

1.8 How Brain Takes Decision

Heekeren et al., inspected and illustrated the action of distinctive brain parts. Like, prefrontal range has common fundamental choice making, free of jolt, and response modalities. Their results are moreover consistent with reports that sores in the back DLPFC prevent unexpected isolation endeavors in both monkeys and individuals. Others have proposed that the capacity of the prefrontal cortex is to manage development along task-applicable pathways from lower-level material locales to zones that course of action and execute responses. They moreover displayed a framework for how perceptual fundamental administration strategies may be begun up within the human mind, utilizing a decently direct subtraction instrument. What stays to be shown is the implies by which this show can represent extra variables that influence the fundamental authority handle, for case, the ordinary estimation of various choices, the prior probability of the nearness of different options and their interior valuation. In the perfect utopia, these studies and frameworks will furthe help drive away the mist that surrounds humans while making a decision and aid in making better choices.[44] .

1.9 Neurons and Neuromarketing

The current revelations present us with imperative bits of information into the temporal and spatial methods supporting human worth based choice making for parallel choices. We appear that worth sign identified with the result of the choice create interior 200 ms after the starting of the choice preparatory, most dominatingly in back zones within the locale of the LIP fair as in back transitory projection cortex, however in expansion less recognizably in a front cortical locus. These disclosures propose a significant work for back intellect zones recalling the LIP for the age of the choice itself, possibly through cortical collaborations with dynamically front areas, for example, vmPFC. Other than, whereas dmPFC was found to report the refinement in esteem among unchosen and picked options as in different past investigations, this sign didn't create until a few other time within the preparatory, generally 1050 ms after the basic update presentation, and 850 ms after the essential rise of the worth sign reflecting the result of the choice (picked regard signals). These discoveries propose that dmPFC may not assume a profound work within the underlying development of the choice itself, however or maybe may contribute at an afterward arrange during the method of execution of action choice.

1.10 EEG Based Communication

A definitive point of this investigation is to construct up a computer interface based on EEG for the reason of utilizing by people with genuine physical confinements. Which would energize communication with a bundle of word-processor or specialist of different characteristic controls. In this paper, they coordinated two particular methodologies. (1) Offline ponders and (2) Online Framework. Within the occasion of offline thinks about, William Penny and Stephen Roberts et al. found this investigate was accommodating in firmly building up that motor imagery signals which can be found by complexity and spectral features. On a crucial level, for driving cursor developments they may well be utilized. It moreover recognized the ideal positions to put anodes in.

1.11 EEG Signal Application in Neuromarketing

In a research by Mahendra et al. they suggested a prescient modeling structure to comprehend customer decisions towards E-commerce items as far as different preferences by dissecting EEG signals [21]. They utilized the Emotiv EPOC+ tool to catch EEG signals. The EEG signals were recorded from volunteers of different age and sex while they were going through different customer items. In the first place, they introduced a Neuromarketing structure for anticipating shopper inclinations while they see E-commerce items by breaking down EEG signals. The authors have demonstrated that characterization of items utilizing EEG signals was superior to anything the rating based order which was accounted for as 80% and 60%, separately when 30 pairs of shoes were arranged into two classes. The EEG signal data were recorded while the members watching virtual 3D items. The authors likewise suggested a customer decision inclination displaying structure for film trailers utilizing EEG signals. Where they have demonstrated diverse decision sets to 18 clients to

research the distinctive mind exercises during basic leadership utilizing the EEG flag and eye tracker tool. The sign experiences certain signal preprocessing and feature extraction steps. Preprocessing and feature extraction being done to the signals, where they displayed the subtleties of the signal smoothing system that is utilized to preprocess the signal for feature extraction. A Raw EEG signal being smoothed. Discrete wavelet change based highlights DWT is generally utilized in biomedical sign preparing in light of the fact that it speaks to a sign in time-recurrence area. The EEG signals utilizing every one of the 14 channels have been recorded from 25 members while seeing shopping items on the computer screen. A variety of items with various shading and surfaces shows the variety in the EEG signals of three unique members for a similar item according to their decisions for the item. EEG signal reaction against channel 'AF4' Product saw by three unique clients' brain action map while viewing the items the decision inclination for the item Figure. Customer choice classification where they displayed the decision inclination results utilizing the sequential HMM

1.12 Classifiers

In a paper, Fabien et al. talked almost classiers. Classifiers alludes to the algorithms that learn from preparing information and can foresee classes for test information. Classes are also known as labels/targets. Classification is the method of building a mapping function from non-target factors to target factors. For illustration, a music recommendation system can be a classification issue where clients are suggested melodies based on the tunes they regularly tune in to.
In this issue, the characteristics of the tunes they tune in to can be non-target variable or input factors and the tune proposals can be target/output variables. When there are two conceivable results of a course for a given dataset the classification assignment is known as double classification and multi-class classification otherwise. There are numerous sorts of classification models based on the strategy of classification. The most prevalent ones incorporate Back Vector Machines, K-Nearest Neighbors, Trees, Neural Systems, Gatherings, etc.
Which classification show will deliver the most excellent comes about depends on the kind of data and its applications. A few classifiers do a few specific assignments way better than other classifiers. For illustration, SVM oversees exceptions way better than others. So, choice of a proper classification calculation needs appropriate examination of the dataset and the application. There are different ways to calculate the viability of a classifier. For example, holdout strategy, cross-validation strategy, roc bend, etc. In holdout strategy, data is separated into tests and preparing information. The demonstration is prepared with preparing information and then test information is utilized to compute its exactness of foreseeing the proper output. The cross-validation strategy separates the dataset into k equal-sized segments. One partition is utilized as testing information whereas others are utilized for preparing. This process is iterated k times and normal precision is computed. This strategy produces the best comes about against overfitting. ROC or Collector Working Characteristic curve represents the trade-o between genuine positive rate and untrue positive rate. When the area beneath the ROC bend is near to 1 the models exactness is high.[33].

1.13 Signal Processing

Signal processing alludes to the examination of signals such as sound, picture, and biological measurements. The innovations that drive our day to day life is fueled by signal processing. Momentous enhancement of clinical examination and location of diseases and variations from the norm was conceivable much appreciated to brain flag preparing.

Within the book by Saeid et al. the journalists talked about the most recent headways in flag taking care of and mechanized procedures that are required to bolster the key parts of future headway in biomedical investigate and development, particularly on the modern estimations and evaluation of signals and pictures from the human body.

There are different categories of flag preparing depending on the application. For example, analog, continuous-time, discrete-time, computerized, non-linear, measurable, etc. Analog flag preparation is for non-digitized like tv, radio signals. Continuous-time flag preparation is for signals that change for the altar of a continuous domain. Discrete-time flag preparing is for discretely tested signals. Digital signal preparing is for preparing discretely tested digitized signals. Non-linear signal preparation is for preparing signals delivered from non-linear frameworks. Statistical signal preparing is for handling signals utilizing their factual properties.

1.14 Neuromarketing: Bridging the Gap Between Producer and Consumer

Many refer to neuromarketing as the boiling pot for psychology, neuroscience and marketing. The sensory-motor, psychological and difference in brain signals are observed for producing better advertisement tools. Soumala et al. proposes to use to method and suggested that it can be used to discover brain enactment during consumer interaction. The researchers have developed a virtual simulation of a consumer's walkthrough to study consumer's response to specific advertisements. The consultative selling consists of five stages and they are: (1) Creating customer connection, (2) Understanding customer needs, (3) Addressing customer needs, (4) Closing the sell, (5) Establishing a sustainable relationship. Neuromarketing is more prevalent than conventional showcase studies and inquires about. Even though it can't make buyers come to a conclusion with respect to their choice of purchase, it can certainly offer assistance them get to that organize since chance shifts from individual to person. With respect to this, analysts couldn't clear up remarking variance and saw a change in their investigation.

The authors have utilized fMRI all through this virtual customer travel to record the brain signals of buyers. The information at that point being pre-handled, a fashion framework was outlined that was utilized as a course of action for anticipated intellect activity, and moreover, the connected quantifiable test examination was performed on the nonheritable data. Creators have specified that gathering electroencephalography (EEG) with useful attractive reverberation imaging (fMRI) can be a non-invasive method for the think about of the human brain. Indeed in spite of the fact that it has been practiced as a parcel, the method still is exceptionally complicated and a conventional method for information analysis is to be built. Amid this

ponder, we had to diagram numerous challenges with respect to each step of the data examination pipeline in EEG-informed fMRI and given a graphic clarification and representation of the overplus of ways out there to oversee all the challenges. The motivation crucial the journalist, multimodular acquirement of graphical record and fMRI was first included, at the side a expedient portrayal of 11 the fundamentals of each neuroimaging strategy. Graphical record and attractive resonance imaging(MRI) information quality were given special focus since they are the foremost vital factors, through classifying the artifacts iatrogenic by each methodology on the inverse, in addition since the foremost significant modality-specific artifacts and clarifying the person entirely decrease strategies.

At long final, we'll in common be centered on multi-modular data coordination interior the setting of the EEG- educated fMRI approach, degree each univariate and variable ways acclimated remove graphical record choices that will expect courageous sign changes. This exceptional survey might energize the recognizing confirmation of the strategy pipeline that most eagerness ts each think about, in arrange to streamline data quality in addition in light of the reality that the affectability and particularity of the cerebrum frameworks got by EEG-educated fMRI examination. The perfect framework for the mix of data from the 2 modalities remains accomplice open request, fundamentally since of a more significant comprehension of the substrates of each strategy and moreover, the degree to which these substrates cover remains required. In expansion, a ton of interior and out, essential and free endorsement considers are required to oversee the understanding of the disclosures procured to abuse the ways diagram over [11]. As science moving forward with the pace of light we will without a doubt trust for a bridge of steel and believe between maker and customer.

Chapter 2

Literature Review

Even though incorporating brain signal analysis to develop better marketing strategy is a relatively new practice, several research approached the issue and proposed different models that aided the effort of predicting certain consumer behaviors. Some studies also tried to determine the impact of brain signal analysis in marketing. A few honorable mentions are discussed in this paper. A research conducted analysis of EEG signals to predict consumer's preferences in certain categories [21]. The experiment was conducted on 40 participants, 25 males and 15 females. They have used Emotiv EPOC+ for reading brain signals. There were 14 different product categories. Each category of product had three different varieties the participant could choose from. After viewing each category of product, the participants were asked for their preference of the product in terms of two classes, 'like' or 'dislike'. They have used an S-Golay filter for signal smoothing. Discrete Wavelet Transform (DWT) based wavelet analysis has been performed for feature extraction. HMM (Hidden Markov Model) was used for consumer choice classification. Their model had 65% accuracy on average. They have also done age and gender based prediction comparison and have found that their model was more successful predicting the choices of male participants. Another research intended to determine the effectiveness of neuro-marketing in current scenarios by analyzing the use of neuro-marketing by various companies to increase their sales [45]. The study has found that several companies have used brain signal analysis to improve their products. According to the study, Hyundai Motors uses EEG signals to measure consumer reactions during the design process of their vehicles, while the consumers look at specific parts of the vehicles. They later use this data to make necessary changes in their vehicle design. Frito Lay, the American snack producer has also used neuro-marketing. They found that the glittering, bright colored packaging used in 2008 for potato chips activated the brain's anterior cingulate cortex, a region associated with feelings of guilt. They again tested with matte beige colored packaging and found no adverse effects on the consumers. Thus they changed their packaging. Yahoo tested the effects of a video commercial that they made, on consumers with the help of EEG before spending the money airing the commercial on TV. The study also found that several companies were taking help from companies specialized in brain signal analysis to improve their products. The study further talks about the different tools of neuro-marketing such as EEG, FMRI, Eye Tracking etc. An E-commerce product recommendation system was proposed in by taking into account, both pre-purchase and post-purchase ratings. In their proposed system, consumers are to visit a virtual store [12]. In

their paper, they talk about a virtual t-shirt store where a range of t-shirts were displayed. Consumers are able to interact with the products and even try them on. Brain signals of the consumers are read using EEG during the process which served as pre-purchase ratings. The proposed model is able to determine the likeness of a product by analyzing brain signals of consumers. Post-purchase ratings are to be given by consumers after the physical purchase of a product. The proposed model combines both pre-purchase and post-purchase ratings to recommend similar products to the consumer's liking. If post-purchase ratings do not exist for a certain customer, the proposed model gives recommendations based on pre-purchase rating. If pre-purchase ratings do not exist, the model gives recommendations based on post-purchase ratings. If both do not exist, the model cannot give any recommendations. A neuro-marketing system was proposed in order to predict the most preferred automobile brand among four popular brands in Malaysia namely Toyota, Suzuki, Proton and Audi [15]. Four video clips each representing a brand were shown to participants. The brain activity of the participants was recorded using EEG during the process. After each video, participants were presented by questions regarding like or dislike, the intensity of like and dislike and emotion experienced during the clip. Data was collected from 12 participants consisting of 9 males and 3 females. Emotiv EPOC wireless EEG headset was used to derive EEG signals. Butterworth band pass filter was used to remove low and high frequency noises and power line interference noise from raw EEG signals. A Laplacian filter was used for further smoothening the processed signal. Fast Fourier Transform (FFT) is used to derive spectral characteristics from the EEG signals alpha wave (8Hz–13 Hz). Butterworth 4th order filter is used for extracting the alpha wave from each framed signal and extracting three statistical features including Power Spectrum Density, Spectral Centroid, and Spectral Energy. K-nearest neighbors (KNN) and Probability Neural Network (PNN) were used for classification. The study found that the participants found Toyota to be more appealing than the others. A study has proposed a forecasting system for footwear by analyzing EEG signals [16]. Thirty shoes were tested in the study. Data was taken from forty female participants. The study conducted their experiment in two parts. In the first part, they set up a mock store where all the thirty shoes were displayed along with their price. The participants could touch and even try the shoes on. After that they were asked to rate the shoes from 1 to 5 with 1 being the lowest and 5 being the highest. In the second part of the experiment, the participants were presented with images of the shoes that they saw in the first part and their EEG signals were recorded. The study found that brain data could predict consumer behavior much more successfully than traditional questionnaire methods. The first scholarly piece of neuro-marketing research was performed by Read Montague, Professor of Neuroscience at Baylor College of Medicine in 2003 and published in Neuron in 2004 [10]. The study asked a group of people to drink either Pepsi or Coca Cola while their brains were scanned in an fMRI machine. While the conclusions of the study were intriguing, Dr Montague failed to provide a rationale for how our brain handles brand choices. Nevertheless, the study did reveal that different parts of the brain light up if people are aware of or not aware of the brand they consume. Specifically, the study suggested that a strong brand such as Coca Cola has the power to "own" a piece of our frontal cortex. The frontal lobe is considered the seat of our executive function (EF) which manages our attention, controls our short-time memory, and does the best of our

thinking, especially planning. So according to the study, when people know they are drinking Coca Cola, they actually say they prefer the Coke brand over Pepsi and their EF lights up. However, when they don't know which brand they are consuming, they report that they prefer Pepsi instead. In this latter event, the part of the brain which is most active is not the EF but an older structure nestled in the limbic system. The brain area is responsible for our emotional and instinctual behaviour. Furthermore, Kosslyn (1999, p.1283) stated the following regarding neuroimaging studies: "Many of the studies summarized in the posters did not seem to be designed to answer questions about the functioning of the brain; neither did they seem to bear on specific questions about the roles of particular brain regions [5]. Rather, they could best be described as "exploratory." People were asked to engage in some task while the activity in their brains was monitored, and this activity was then interpreted of post hoc. In their recent critique of the brain mapping paradigm. Lee and Chamberlain (2007, p. 23) propose that "...there is also a chance that the end result of the present approach is a set of neuro-whatever ad hoc research studies that are not necessarily theoretically driven. In such cases, we may fall unsettlingly prey to exactly the kind of blobological approach that has received criticism in social and general neuroscientific circles." Numerous other scholars have questioned the value of the brain mapping paradigm including Uttal (2001) who referred to the endeavor as a new form of phrenology, as well as the Neuro-science Institute (fMRI Colloquium Series) at Stanford University who sponsored a debate on 30 November 2005 titled "The great debate of 2005: Is fMRI just a waste of our time? Can we learn anything useful from functional neuroimaging. It is our contention that some of the criticisms levied against the neuroimaging paradigm in general and neuromarketing in particular would be assuaged via the adoption of evolutionary theory as the organizing theoretical meta-framework. In another work, gender has been found to have a moderating effect on decision making [3]. For example, Fischer and Arnold (1990) found gender roles to be associated with involvement in Christmas shopping. Men with more feminine gender roles, like women, were more involved. Similarly, but to a lesser extent, gender identities were associated with greater involvement. Adam et al. (1999), in a study of 12 male and 12 female participants, found men to have faster reaction times and surmised this may be due to differences in brain processing strategies. Herrmann and Crawford (1992) found that gender stereotypes correlated with memory tasks e.g. women were relatively more successful at memorizing grocery (but not hardware) shopping lists than geographical directions. Furthermore, women are more likely to use shopping lists (Block Morwitz, 1999). Broadly speaking, easier decisions, such as those based entirely on observed characteristics, would be expected to be quicker. Brand choice involves memory and probably emotional activation not required for a more simple discrimination task, e.g. comparing the heights of three packages (Gross, 1995). Accordingly, reaction times for brand choice should be longer than for relative height determination (issue 1 or I1). Secondly, where one brand is more familiar than the others, the decision is likely to be faster than for equally familiar or unfamiliar brands (Dhar Nowlis, 1999). A variety of brain imaging studies has provided evidence for specific neural substrates associated with semantic processing and the memory-based interpretation of visually presented material (McCarthy, Nobre, Bentin, Spencer, 1995; Braeutigam, Bailey, Swithenby, 2001a; 5Damasio et al., 1996; Nyberg et al., 1996). Brain activation differences, therefore, should be observed between brand choice and height discrim-

ination when the same visual images are used. It leads to the expectation that male and female brain activations will differ. And finally, in line with Damasio (1994), brand choice decisions were expected to be associated with activations in the frontal lobe (e.g. VM in Figure 1) (I5). This was the only location clearly predicted by the literature but the research was, probably more importantly, directed broadly to look for any significant activation differences between brand choice and height determination.

Chapter 3

Background Study

3.1 Human Brain

The human brain is the foremost imperative and complex organ of the human body. The brain retains the central portion of our anxious framework. It is associated with more than a billion neurons and the neurons have more than trillion connections to communicate with each other in this way, controlling all our sensory and motor functions. The brain is arranged interior the head close all the other neural organs [24]. The most capacities of the brain are engine control, tactile, cognition lateralization, feeling, dialect, and direction. The brain is generally composed of 3 major sections that are the Brain Stem, Cerebrum, and Cerebellum.

3.1.1 Brain Stem

The position of the brain stem is fair underneath the cerebrum. The brain stem connects the spinal line with the brain. It acts like a depend on the center by interfacing the cerebellum and the cerebrum with the spinal line. The brain stem comprises of three parts which are medulla oblongata, midbrain, pons. This portion of the brain is made out of a blend of white and dim matter. The brain's wake and rest cycles are controlled by this part of the brain conjointly muscle tone of the body is controlled by the brain stem. Body functions such as blood weight, oxygen levels, vomiting, wheezing, hacking, swelling re exes, homeostasis is managed by this portion of the brain.

3.1.2 Cerebellum

The Cerebellum is arranged behind the Brain Stem and underneath the Cerebrum [27]. The posterior and front flaps of the cerebellum are connected within the center by the vermis. It looks like hemispheric and is wrinkly. Fundamental assignments of the cerebellum to control the motor capacities like pose, adjusting, and adjusting muscle activities. It too manages the synchronisation and tactfulness of human engine exercises like strolling, composing, and speech.

3.1.3 Cerebrum

The cerebrum is the greatest portion of the brain. It has both cleared out half of the globe and right half of the globe. Both of these halves of the globe are associated with bers called corpus callosum. The cleared outside of the equator of the cerebrum controls all the exercises of the right half of the body and bad habit versa. The cerebral cortex covers the inside white matter which itself is the external layer of dark matter. corpus callosum sends data from one side to the other side of the cerebrum. In any case, each side of the brain has a few capacities doled out to them freely. For illustration, composing, calculations, cognitions, discourse are relegated to the cleared out portion of the brain whereas the correct side controls spatial capacity, creative ability, inventiveness, melodic fitness, etc. The cerebrum is the greatest portion of the brain. It has both cleared out half of the globe and right half of the globe. Both of these halves of the globe are associated with called corpus callosum. The cleared outside of the equator of the cerebrum controls all the exercises of the right half of the body and bad habit versa. The cerebral cortex covers the inside white matter which itself is the external layer of dark matter. corpus callosum sends data from one side to the other side of the cerebrum. In any case, each side of the brain has a few capacities doled out to them freely. For illustration, composing, calculations, cognitions, discourse are relegated to the cleared out portion of the brain whereas the correct side controls spatial capacity, creative ability, inventiveness, melodic fitness, etc. The cerebrum is the expansive, external portion of the brain. Considering, judgment and decision making is basically controlled by this portion of the brain. The cerebrum controls reading, considering, choice-making, learning, discourse, feelings, identity, reasoning, planned muscle developments like strolling, vision, hearing, and other senses [13]. The cerebrum comprises of 4 flaps: (1) Frontal flap, (2) parietal projection, (3) occipital lobe, (4) worldly flap.

Frontal Lobe

The frontal lobe is found within the front portion of the brain. It assists in motor functions, self-awareness, functions related to writing and speech, intelligence, judgment, planning, problem-solving, and feelings

Parietal Lobe

The parietal lobe is located behind the frontal lobe. It is called parietal lobe as it is close to parietal bone. It encompasses a somatosensory cortex and assists with processing sensory data to decide touch, sense of torment, and temperature.

Occipital Lobe

The occipital lobe is located at the back of the brain [38]. It contains a visual cortex that, receives visual data from the eye. this data is handled in this lobe to make choices of color, discernment, and vision.

Temporal Lobe

The temporal lobe is found on the side of the brain and assists with learning, memory, feeling, and dialect. It contains the sound-related cortex which processes audi-

tory data.

3.1.4 Traveling of Brainwaves In Neurons

More than nearly a billion neurons are associated with each other interior of our brain. These neurons communicate and exchange data with each other through electrochemical pulses. Pathways of these beats are made of nerve cells (neurons), brain cells, and glial cells. Neurons essentially comprise of 3 segments. They are a cell body, dendrites, and axons. Dendrites is obligated for moving messages from neurons. Axons are found toward the nish of the cell, neurotransmission happens among axon and a dendrite. The glial cells at that point once more empower neurons by ensuring neurotransmitters are transmitted suitably. In this way, mind messages of motor exercises or different responses to overhauls make a trip through the nerves to the objective muscle, organ, or cell. On the off chance that there ought to be an event of feeling, intellect sends flag right to the unequivocal muscle to coordinate the response. For instance the tearing of eyes due to experiencing a specific feeling.

3.1.5 Brainwaves

The monotonous Electrical beats in our central anxious framework is called "Brain Waves" [6]. These neural motions dependable for neural transmission are measured in Hertz (cycles per moment). Beats produced from either a neuron or due to interaction between two neurons. Data is passed onto the target muscle or goal through the anxious framework in arrange to perform engine activity, send sensory data, or fair virtual data. Hence brainwaves differ based on what data or instruction they are communicating. High-frequency brainwaves can be watched when a human is delighted, on the other hand, low-frequency brain waves can be watched when people feel sluggish or bored. The diverse brainwaves of the shifting recurrence extend can be watched through an EEG. They can be classified according to their recurrence run into five sorts.

Types of Brainwaves

As of now specified prior, brainwave recurrence can be classified into five types. which are: (1) alpha, (2) beta, (3) gamma, (4) delta, (5) theta

Alpha

Alpha waves extend between frequencies 8 Hz and 13 Hz [41]. This low-frequency range is due to the reality that they are produced when the brain is calm and in a relaxed state. It is additionally produced in a keen or reflective state of intellect .

Beta

Beta waves run between frequencies 13 Hz to 38 Hz [47]. Since it is generally created in the frontal flap, this implies it is created amid cognitive errands, problem-solving, planning, self-awareness. When people are effectively taking an interest or doing tasks that require consideration, brainwaves in this recurrence run can be watched .

Delta

Delta waves run between 0.5 Hz and 3 Hz [33]. It includes a recurrence extend lower than that of Alpha waves. Thus it is only created whereas encountering profound rest, and there's no mindfulness of the environment at all. Amid this stage, the human body recovers and recovers.

Gamma

Gamma waves have frequencies higher than beta waves, they extend from 38 Hz to 42 Hz. Being over neuron ring recurrence, it is frequently related to a broader consciousness. Initially, it was considered as commotion and disposed of, till afterward on it was found out that it is dynamic within the states of 'high virtue' [49].

Theta

Theta waves extend between 3 Hz to 8 Hz. It lies between alpha and delta waves and can be watched amid reflection or whereas imagining this extend humans tap into their subliminal intellect [49]

3.2 EEG Analysis with Various Algorithms

German neuropsychiatrist named Hans Berger discovered human electroencephalogram (EEG) [14]. In 1929 He suggested that brainwaves can be measured and recorded by putting anodes on the human cranium. He got a part of feedback for this strategy of his. However, the feedback did not halt analysts and researchers from delving into this field. in spite of various criticism and socially frowned upon [46]. EEG gadget is called non-invasive as it does not require any operation that requires insertion in the brain or inner tissue. EEG permits anodes to be mounted on the human cranium which captures brain waves from electrochemical boosts within the brain's neurons. To order to make them obvious on a paper or screen, electrical chemical signals are generated by the EEG framework and passed on to an amplifier. The EEG has gotten to be the best method for the discovery of brain waves, a straightforward component, and a noninvasive system [20]. Data from the terminals of the EEG cap can be exchanged in different methods such as Bio-Semi, B-Alert, and Bio-radio 150. whereas recording brainwaves the EEG machine picks up different clamors due to eye squinting, muscle development, conjointly instrument clamor. To dodge irregularities, the commotion is expelled

Support Vector Machine

SVM separates points of two classes using a line that's most distant from both the focuses. This line is called a hyper-plane and draws the choice boundary between the two focuses. the hyper-plane ensures the most elevated conceivable separate between the focuses to guarantee tall classification exactness.

3.2.1 Discriminant Analysis (DA)

Discriminant analysis algorithm finds a combination of predictors that separate the two classes in the best possible way. There are various discriminate types used in this algorithm such as linear discriminate, quadratic discriminate, diagonal-linear discriminate, diagonal-quadratic discriminate, pseudo-linear discriminate, pseudo-quadratic discriminate. In our classification, we have used quadratic discriminate. It looks for a set of conditions utilizing input factors, which are utilized to classify the information into classes. The most objective of this calculation is to get it the relationship between the input factors and the yield factors. Discriminant Investigation is exceptionally closely related to Relapse Examination. The most contrast between these two calculations is that Relapse Examination bargains with continuous input factors and Discriminant Investigation bargains with discrete input factors. In both calculations, the input factors are plotted against the yield factors. Discriminant Examination is additionally exceptionally closely related to one-way MANOVA. The main difference is that the parts of the factors are turned around in MANOVA.

Decision Tree

Decision Tree classifies information by persistently part them based on distinctive conditions. Each hub of the tree inquires a distinctive address. Depending on the boolean answer another hub is chosen and the final hub yields the anticipated lesson for the data. The longer the tree, the more complex and fitter the show. The arrangement of the nodes is chosen by data pick up the property of each condition.

Naive Bayes (NB)

Naive Bayes is an exceptionally well known classier that works truly well indeed with a small dataset. Numerous genuine world issues counting spam filtering is illuminated by this simple machine learning calculation. Naive Bayes is a very quick learner compared to other more complex machine learning classifiers. The key presumptions in this algorithm incorporate, the autonomy of the highlights and their rise to a commitment to the yield.

K-Nearest Neighbors (KNN)

KNN could be a kind of apathetic learning calculation, where the key computations are done while classification instead of whereas preparing. As a result, the preparation time can be quite quick for KNN calculations. In any case, the testing time is truly moderate. 'k' in KNN represents the greatest remove between neighbors that ought to be considered. In this calculation, the neighbors that are near, contribute more towards the average than the ones that are more distant. For illustration, the weight of each neighbor is calculated by 1=d, where d indicates separate.

Random Forest

Random Forest is another exceptionally prevalent machine learning classification algorithm that as the title proposes, classifies information by averaging yield factors from a large number of choice trees. In spite of the fact that Decision Trees are demonstrated to be exceptionally probable in classification issue understanding, they

are not exceptionally successful for non-linear regression. However, employing a huge number of them together definitely progresses precision at the cost of elucidation capability of the yield.

3.3 EEG

The term Electroencephalography can be isolated into 3 parts. Electro is brief for electrotype or electroplate, encephalo implies the brain and gram stands for the study or report of something. In this manner, it can be said that the electrical motivations of the brain can be caught on with the assistance of EEG. In arrange to do so, first electrodes are required to be set at key focuses on the head so that the anodes can detect and degree EEG signals. These signals are at that point engraved and physically documeted in wave structure [20]. It can be said that the particular unit of the brain are neurons. In spite of the fact that there are many other cells within the brain other than neurons, be that as it may, movement of impulses happens in as it were neurons. The transportation of drive happens in the frame of electrical activity. For the most part, all other body cells compare to each other with chemicals. For instance, they communicate with each other through dopamine. Be that as it may, neurons use electrical motivations to exchange data between them [7]. To get it what electrical action implies we got to get utilized to a number of terminologies. Terminologies such as 'cycles per second' or 'voltage' can be a few times when working with EEG signals. These phrasings are truly imperative to understand the electrical association and communication interior of the brain. Whereas communicating with each other, neurons exchange electrical motivations between them. To create that drive a little sum of power is created interior our brain. By 'voltage' we get it the size of electrical action. Meaning, the strength of the power ring. On the other hand, 'Cycles per second' represents the recurrence of the firing and amount of timess a neuron sending data to other neurons in a moment [20]. Synchronicity implies two concurrent things working or being within the same state. If two or more neurons re within the same heading at the same time at that point it can be said that the neurons synchronous. The voltage or sum of electrical motivation is not considered in this case. As it were their course and timing matter. These neurons are said to be in synchronicity if they send electric motivations at the same time. However, if the heading is inverse or diverse at that point the neurons are not in sync, they are then called non-synchronous. Able to include up the electric impulse signal of the neurons that are in match up. Including them up will give the final result that adds up to electric motivation. Within the case of non-concurrent driving forces on the $o_{c}hancethatitiswithintheexactoppositeheadingincaseofpolaritiesatthatpoint, theywillcanceloutea$

3.4 Neuropsychology

Within the article by [20] Neuropsychology is tended to as a department of psychology and neurology that points to get it how the structure and work of the brain relate to specific mental forms and how the brain and the rest of the nervous framework impact a person's cognition and behaviors. Experts in this branch of brain research basically center on how wounds or sicknesses of the brain affect the cognitive capacities and behaviors of a human being. This can be a scientific approach that offers the

data around handling see of one's intellect with cognitive psychology and science. This specific one among the extra mixed of the psychological methods, covering each presently and after that with ranges like neurobiology, philosophy, neurology, restorative claim to fame, and connected science. That genuinely creating artificial neural systems.

The consider of brain research by and large know as the think about the intellect and neurology refers to the ponder of the brain that specializes in Neuropsychology. A neuropsychologist works to get it the structure and work of the brain and its affiliation between thoughts and behaviors. This extraordinary department of understanding makes a difference in us to memorize how the brain and behavior are associated.

Chapter 4

Proposed Methodology

Workflow represents the sequential steps that were taken to conduct a research. For any kind of research work, planning the workflow is of utmost importance. A

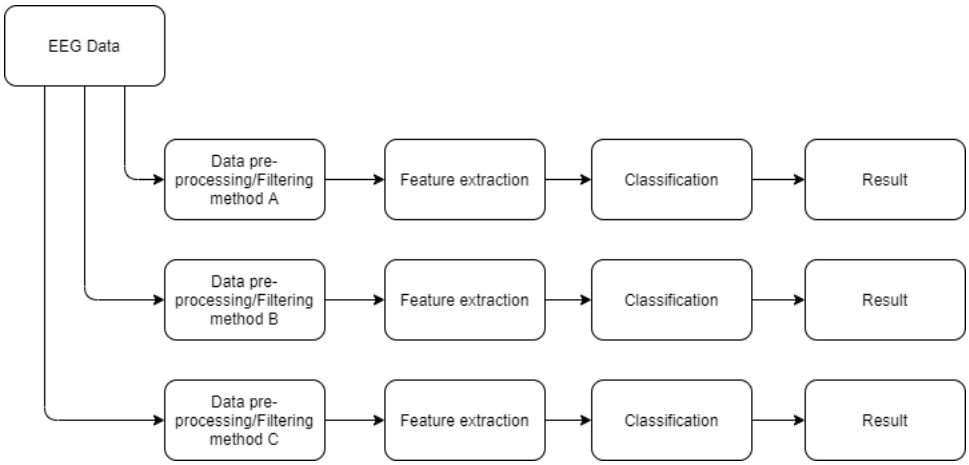

Figure 4.1: WorkFlow

flowchart representation of our workflow is shown in Figure 4.1. In the first step, we collected the EEG dataset. After collecting the data, the data needs to be filtered to remove noise. This step is called dataset pre-processing. We have used three different filtering methods for pre-processing. For each filtering method, we have then extracted the features form the filtered data. These features were then used for classification. In classification, majority of our data was used for training the model and the rest were used for testing. After training, our model was ready for prediction.

4.1 Data Set Collection

For our research purpose, we have used the data-set that were recorded by Yadava et al. [21] The data set had EEG reading of 25 participants each viewing 42 products belonging to 14 different categories. In total, 1050 (i.e. 42 x 25) EEG signals were recorded. The data-set is labeled. Participants were asked to classify the products based on their “like” and “dislike”. The data was recorded using a 14-channel Emotiv Epoc+ EEG headset.

4.2 Data-set Pre-Processing

Recording EEG a bit complex as it is highly susceptible to noise. The noise could come from external sources or scalp activity. These noises make it very difficult to analyze the signal. There are ways to take precautionary measures to reduce noises while recording EEG. However, filtering is also needed to remove noise from the recorded signals. This is where pre-processing comes in. There are various signal smoothing methods available. These smoothing techniques removes the noise from the data and helps patterns in the data to stand out in the process. For our pre-processing, we have used three different filtering methods. They are moving average, median filter and S-Golay filter.

4.2.1 Moving Average Filter

Moving average filter is commonly used to smooth noisy data. Moving average filter creates various subsets of the given dataset. It then returns a series of averages of those subsets. If a subset size and a series of numbers are specified, the first element of moving average is specified be taking the average of the fixed initial subset of the number series. The subset is then modified by excluding the first number of the series and including the next value in the subset which is known as "shifting forward". This filter is best used for removing noise and fluctuations in a time series data and highlights slow trends in the data as a result.

$$y[n] = 1/N \sum_{i=0}^{N-1} x[n-i] \tag{4.1}$$

4.2.2 Median Filter

Median filter is a popular non-linear filter that is widely used for image and signal pre-processing. Median filters can preserve sharp edges while removing the noise. Median filter runs through the data entry by entry while replacing each entry with the median of other entries around it. The pattern of these neighboring entries are known as "window", that moves entry by entry throughout the whole signal.

4.2.3 S-Golay

Savitzky–Golay filter or S-Golay in short is a digital filter that is used for smoothing the data without distorting the signal tendency. This is done through a process known as convolution. In this process, successive subsets of adjacent data points are fitted with a low degree polynomial by the method of linear least squares. When the data points are equally spaced, an analytical solution to the least square equation can be found in the form of a single set of convolution coefficients that can be applied to all data subsets which gives estimates of the smoothed signal at the central point of each subsets. The benefit of using S-Golay filter is that it can remove the noise from the signal while keeping the peaks in the data. This is helpful in some cases as the peaks represent sudden changes in the data which indicated important information based on the type of the signal. We have used varying polynomial order and frame size for our filter. Notable results are provided in result analysis section.

4.3 Feature Extraction

Feature extraction is the process of extracting important information from the data in order to reduce dimensionality. The method of feature extraction depends on the type of data we are dealing with. Most popular method of feature extraction for EEG data is Wavelet Transform. Wavelet transform decomposes the signal into multiple segments known as wavelets. It takes both time domain and frequency domain into consideration while extracting features. There are two types of Wavelet Transform methods. They are known as Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT). We have used Discrete Wavelet Transform (DWT) for our feature extraction.

4.3.1 Discrete Wavelet Transform

The Discrete Wavelet Transform (DWT) is a form of wavelet transform (WT), in which the wavelets are sampled discretely using scaling and translation parameters. The signals are decomposed into an orthogonal wavelets vector. DWT is used for multilevel feature representation of signal data. In this method, both time and frequency domains are considered. The DWT of a signal x is calculated by passing it through a series of filters. At first, it's passed through a low pass filter g and then a high pass filter h as shown equation (2) and equation (3) respectively.

$$y_a = x(t) * g \tag{4.2}$$

$$y_d = x(t) * h \tag{4.3}$$

From the high pass filter detail coefficients and from low pass filter approximation coefficients are obtained. Then, the filter output of the low pass filter is subsampled by 2 for further processing through new low pass filter g and high pass filter h. The detail coefficients from each level of processing are wavelet coefficients. We decomposed our signal data into five details coefficients also known as gamma, beta, alpha, theta, and delta. We calculated power of each frequency band to use as features for our machine learning classifier using the equation(4)

$$Power(x) = 1/n \sum_{i=1}^{n} x_i^2 \tag{4.4}$$

For each electrode we calculated alpha power, beta power, gamma power, delta power and theta power. Total number of features per instance was number of electrodes multiplied by 5. Total number of instances were 1045. After feature extraction we classified them using different machine learning classifiers.

4.4 Classification

Classification is where the models are trained to predict data according to their target class. After extracting the features from our data, we have used the features to classify the data using various machine learning algorithms.

4.4.1 Support Vector Machine (SVM)

SVM or Support Vector Machine is a linear model for classification and regression problems. It can solve linear and non-linear problems and work well for many practical problems. The idea of SVM is simple: The algorithm creates a line or a hyperplane which separates the data into classes. In this blog post I plan on offering a high-level overview of SVMs. I will talk about the theory behind SVMs, it's application for non-linearly separable datasets and a quick example of implementation of SVMs in Python as well. In the upcoming articles I will explore the maths behind the algorithm and dig under the hood. The objective of SVM is to find a hyperplane in N dimensional space where N is the number of features. This plane distinguishes or classifies data points in the plane. If we have 2 features the plane will be a line. To separate the two classes of data points, there are many possible hyperplanes that could be chosen. Our objective is to find a plane that has the maximum margin, which means the maximum distance between data points of both classes. Maximizing the margin distance provides better results and better foundation to classify new data points accurately. Support vectors are the data points that border the hyperplane. This data points determine the hyperplanes(Line if 2 features) position and orientation [23].

4.4.2 Naive Bayes

Naive Bayes classifier is a probabilistic machine learning model for classification. It is based upon Bayes theorem. Its fundamental assumptions are that each predictor makes an independent and equal contribution to the outcome. Its simplicity makes it useful for classification of large data-sets. Equation(4.h) finds the probability of an event given probability of another event that has already occurred [35].

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)} \tag{4.5}$$

Here in ou proposed method we have utilised Kernel Density Estimation[31].

4.4.3 Random Forest

As the name implies Random Forest classification algorithm is consists of a large number of individual decision trees. The decision trees each vote for a class prediction and the class with highest votes becomes the model's prediction [30]. In our model, we have used 50 trees for training the model.

4.4.4 K Nearest Neighbor

K-Nearest Neighbors is one of the most popular machine learning algorithms due to its speed and predictive power. We used KNN for classification of our features. K in KNN specifies the number of neighbors we wish to include in our case. The optimal value for K is between 3-10 for most data-sets, which produces much better results than any other value of K [39]. We used K=3 for our classification. Distance is calculated using different distance functions. Euclidean Distance and Manhattan Distance functions are defined in Equation(6) and equation(7) respectively.

$$EucledianDistance, D_E = \sqrt{\sum_{i=1}^{k}(x_i - y_i)^2} \tag{4.6}$$

$$ManhattanDistance, D_{Ma} = \sum_{i=1}^{k}|x_i - y_i| \tag{4.7}$$

4.4.5 Decision Tree

Decision Tree is a supervised machine learning classification algorithm. In this algorithm data-set is constantly split into subsets according to certain parameters. Entropy and Information Gain are used to construct a decision tree [40], which can be calculated using the equations (7) and (8).

$$Entropy(S) = \sum_{i=1}^{k} -p_i \log_2 p_i \tag{4.8}$$

$$InformationGainIG(T, X) = E(T) - E(T, X) \tag{4.9}$$

Where $E(T - X)$ =conditonal entropy of T given Variable X

4.4.6 Discriminant Analysis

Discriminant analysis algorithm finds a combination of predictors that separate the two classes in the best possible way. There are various discriminant types used in this algorithm such as linear discriminant , quadratic discriminant , diagonal-linear discriminant , diagonal-quadratic discriminant , pseudo-linear discriminant , pseudo-quadratic discriminant . In our classification, we have used quadratic discriminant. Quadratic discriminant analysis (QDA) is closely related to linear discriminant analysis (LDA), where it is assumed that the measurements from each class are normally distributed [36].

Chapter 5

Result Analysis

5.1 Comparative Analysis

A confusion matrix describes the performance or accuracy of the classification model or classifier through a table where the true values of a set of test data are known. Though the confusion matrix itself is really easy to understand, however, the terminologies related to it is a bit tough to get a hold of. Below is an example through which the terminologies of confusion matrix can be understood easily for a binary classifier:

	Prediction: Negative	**Prediction: Positive**
Actual: Negative	TN	FP
Actual: Positive	FN	TP

Table 5.1: Confusion Matrix.

From this matrix we can see that there are four possible outcome. Which are, 1. true positives (TP): These are cases in which the consumer liked the product and our prediction is correct. 2. true negatives (TN): The consumer did not like the product and yet we predicted right. 3. false positives (FP): Here the consumer did not like the product and our prediction was wrong. 4. false negatives (FN): Here the consumer did not like the product and our prediction was right. We used confusion matrix on our classifier algorithms to determine which algorithm is better by finding out area under curve, accuracy, recall, specificity, precision, f- measure and negative predictive value of the algorithms.

5.2 Area Under Curve

Area under the ROC curve is basically the area between the ROC curve and X axis. It ranges from 0 to 1. The model that is 100 percent accurate has an AUC of 1 and the model that is wrong all the time has an AUC of 0.
In Table 5.2, a tabular representation of area under the curve of different algorithms based on the filter is provided.

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	85.28	66.491	89.856	84.622	94.521	58.595
Moving Average Filter	85.173	66.06	91.239	84.937	94.501	61.56
S-Golay (1, 7)	83.852	73.096	88.823	85.429	94.944	63.214
S-Golay (2, 13)	83.672	73.312	89.349	86.65	95.159	60.855
S-Golay (3, 59)	83.44	74.288	87.704	84.368	95.616	60.749

Table 5.2: AUC of different algorithms based on filtering method.

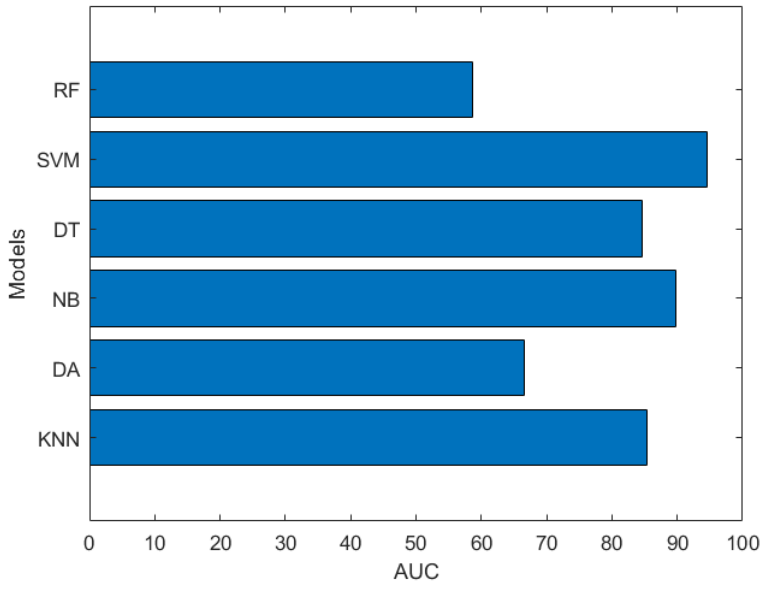

Figure 5.1: Area Under Curve for Median Filter

In Figure 5.1, area under the curve for different algorithms for median filter are shown in a horizontal bar graph.

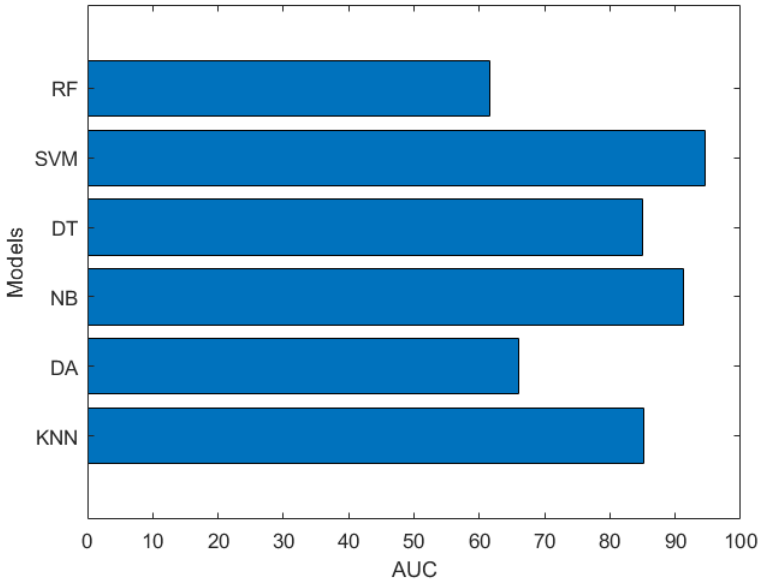

Figure 5.2: Area Under Curve for Moving Average

In Figure 5.2, area under the curve for different algorithms for moving average filter are shown in a horizontal bar graph.

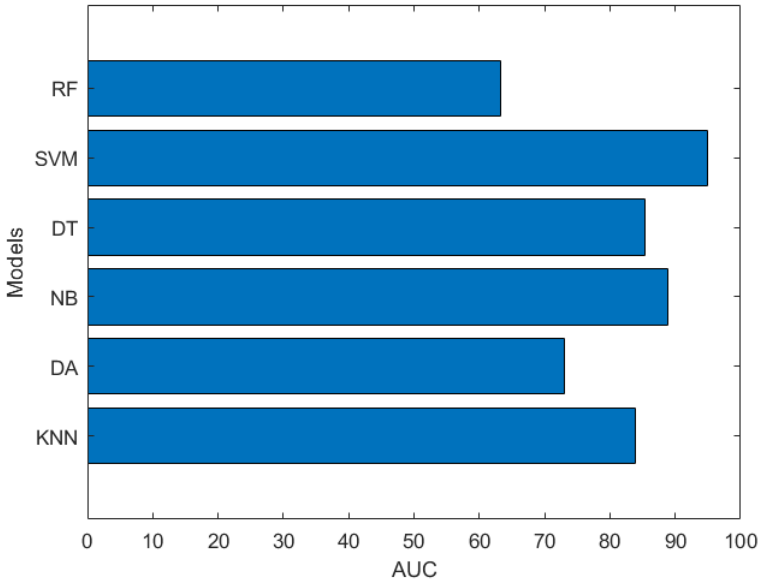

Figure 5.3: Area Under Curve for S-Golay(1,7) Filter

In Figure 5.3, area under the curve for different algorithms for s-golay(order 1, frame size 7) filter are shown in a horizontal bar graph.

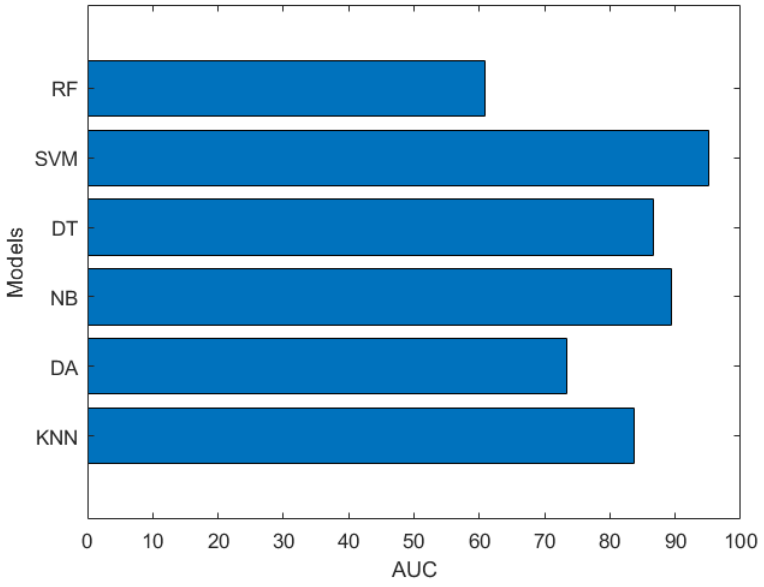

Figure 5.4: AUC for S-Golay(2,13) Filter

In Figure 5.4, area under the curve for different algorithms for s-golay(order 2, frame size 13) filter are shown in a horizontal bar graph.

5.3 Accuracy

The accuracy of a machine learning algorithm is a metric that indicates how often the algorithm classifies a data point correctly. It is the number of correctly predicted data points out of all the data points.
In Table 5.3, accuracy of different algorithms based on the filter used are provided in a tabular representation.

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP} \tag{5.1}$$

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	78.66	60.861	80.957	74.737	85.455	57.225
Moving Average Filter	78.373	59.904	81.244	76.842	86.699	60
S-Golay (1, 7)	77.033	62.967	77.895	75.981	85.933	60.383
S-Golay (2, 13)	76.459	63.445	79.139	79.904	86.795	58.756
S-Golay (3, 59)	76.746	64.976	76.651	76.364	87.56	59.426

Table 5.3: Accuracy of different algorithms based on filtering method.

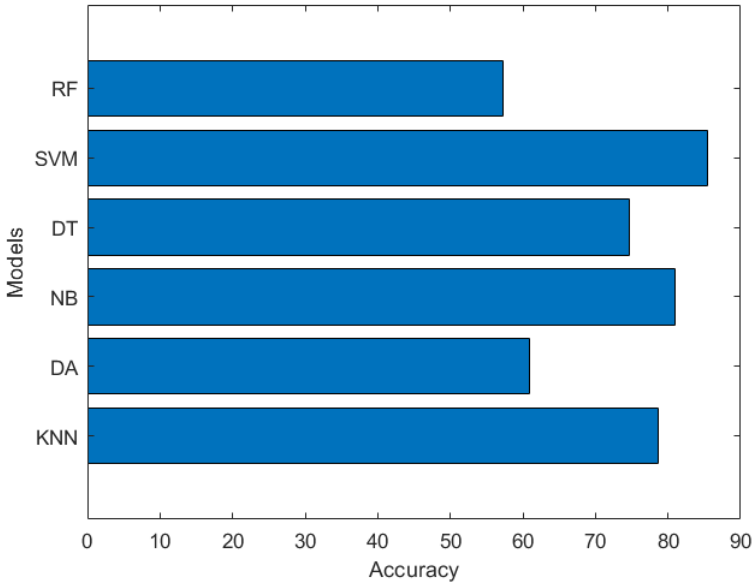

Figure 5.5: Accuracy for Median Filter

In the Figure 5.5, a horizontal bar graph is representing the accuracy of different algorithms for median filter.

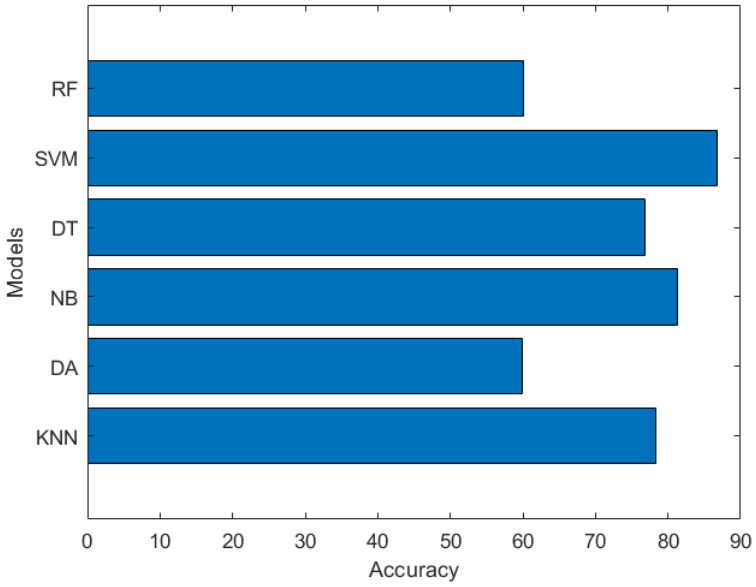

Figure 5.6: Accuracy for Moving Average Filter

In the Figure 5.6, a horizontal bar graph is representing the accuracy of different algorithms for moving average filter.

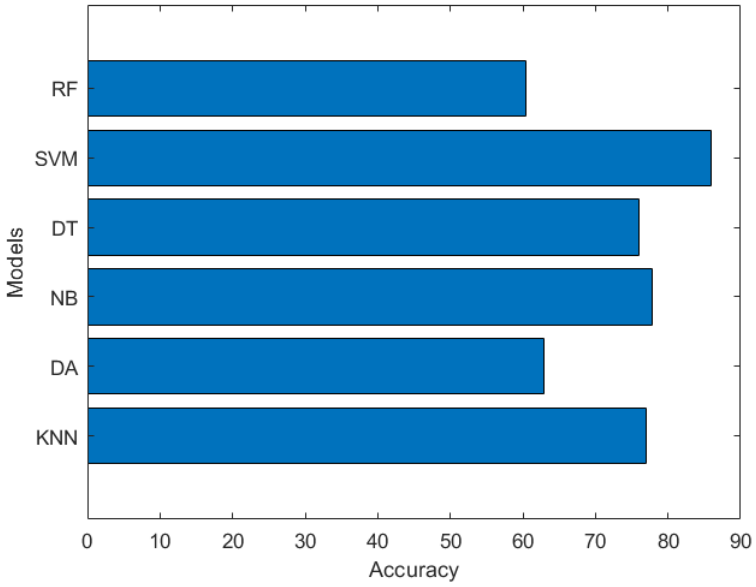

Figure 5.7: Accuracy for S-Golay(1,7) Filter

In the Figure 5.7, a horizontal bar graph is representing the accuracy of different algorithms for s-golay(order 1, frame size 7) filter.

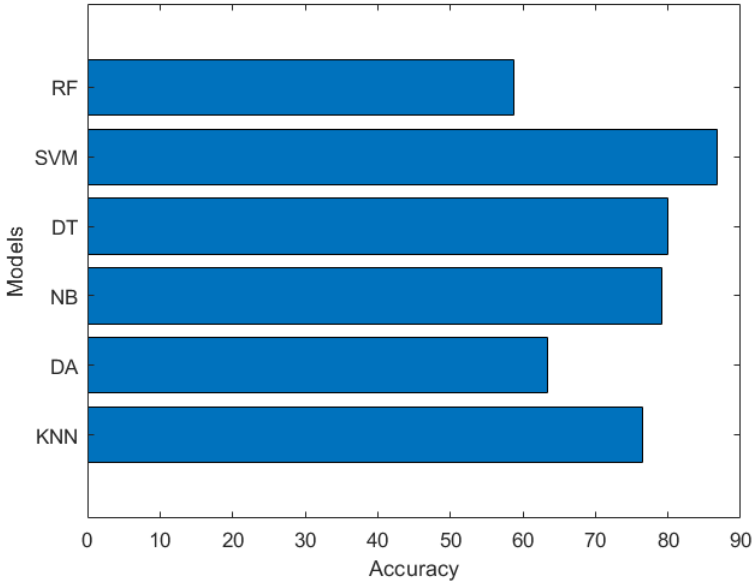

Figure 5.8: Accuracy for S-Golay(2,13) Filter

In the Figure 5.8, a horizontal bar graph is representing the accuracy of different algorithms for s-golay(order 2, frame size 13) filter.

5.3.1 Precision

Precision measures the proportion of accurately identified positives or true positives with the total positive predictions predicted by the model. In Table 5.4, a tabular representation of precision of different algorithms based on the filtering method is given. Precision is defined as follows:

$$Precision = \frac{TP}{(TP + FP)} \tag{5.2}$$

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	77.934	60.156	81.951	79.056	89.922	51.902
Moving Average Filter	77.778	58.537	77.433	76.904	91.71	55.643
S-Golay (1, 7)	75.878	76.812	81.944	85.714	89.447	56.136
S-Golay (2, 13)	75.176	79.699	83.106	75.77	90.074	53.75
S-Golay (3, 59)	75.467	79.503	78.329	77.02	92.112	54.96

Table 5.4: Precision of different algorithms based on filtering method.

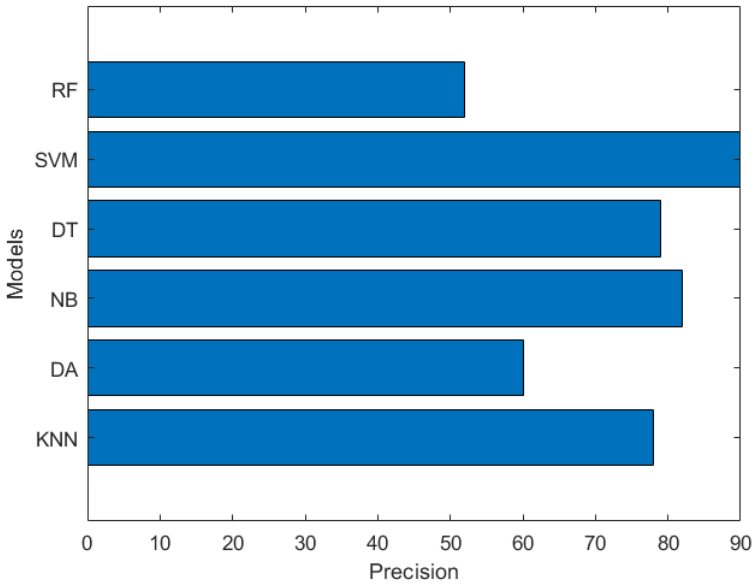

Figure 5.9: Precision for Median Filter

In the Figure 5.9, a horizontal bar graph is representing the precision of different algorithms for median filter.

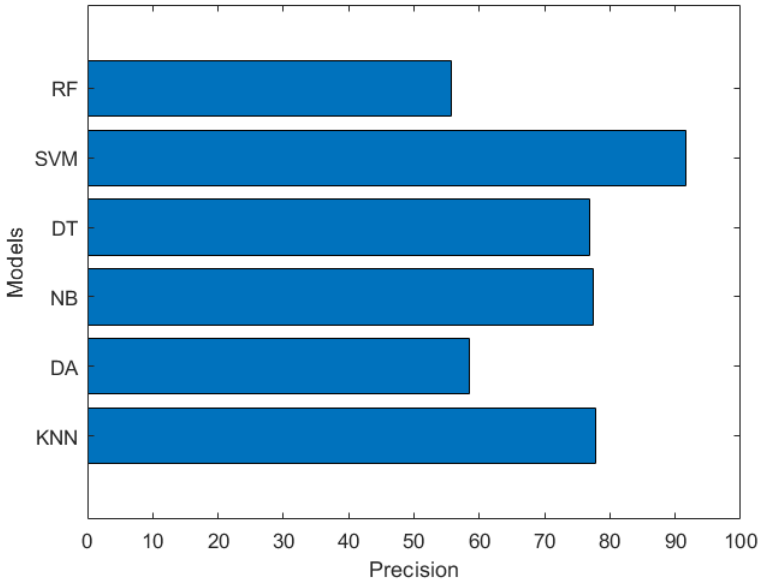

Figure 5.10: Precision for Moving Average Filter

In the Figure 5.10, a horizontal bar graph is representing the precision of different algorithms for moving average filter.

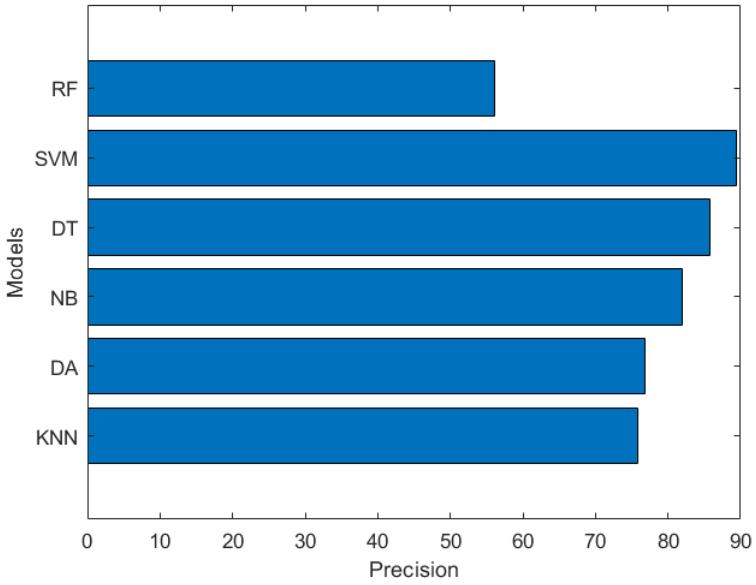

Figure 5.11: Precision for S-Golay(1,7)

In the Figure 5.11, a horizontal bar graph is representing the precision of different algorithms for s-golay(order 1, frame size 7) filter.

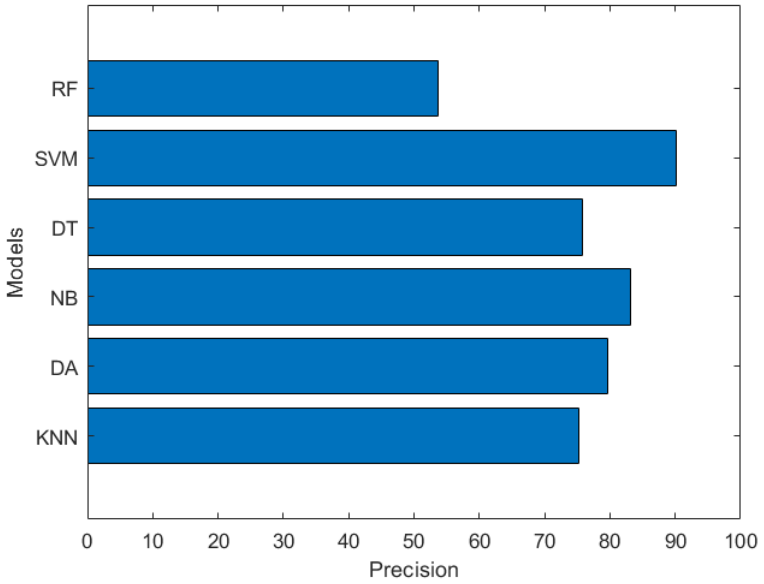

Figure 5.12: Precision for S-Golay (2,13)

In the Figure 5.12, a horizontal bar graph is representing the precision of different algorithms for s-golay(order 2, frame size 13) filter.

5.4 Recall

Recall measures the proportion of accurately predicted positives with the total actual positive outcomes in a particular test set. In Table 5.5, a tabular representation of recall for different algorithms based on the filtering method is provided.
Mathematically, recall is defined as follows:

$$Recall = \frac{TP}{(TP + FN)} \tag{5.3}$$

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	72.017	33.406	72.885	58.134	75.488	41.432
Moving Average Filter	71.367	31.236	81.128	67.896	76.79	45.987
S-Golay (1, 7)	70.282	22.993	63.991	54.664	77.223	46.638
S-Golay (2, 13)	69.631	22.993	66.161	80.043	78.747	46.638
S-Golay (3, 59)	70.065	27.766	65.076	66.161	78.525	44.469

Table 5.5: Recall of different algorithms based on filtering method.

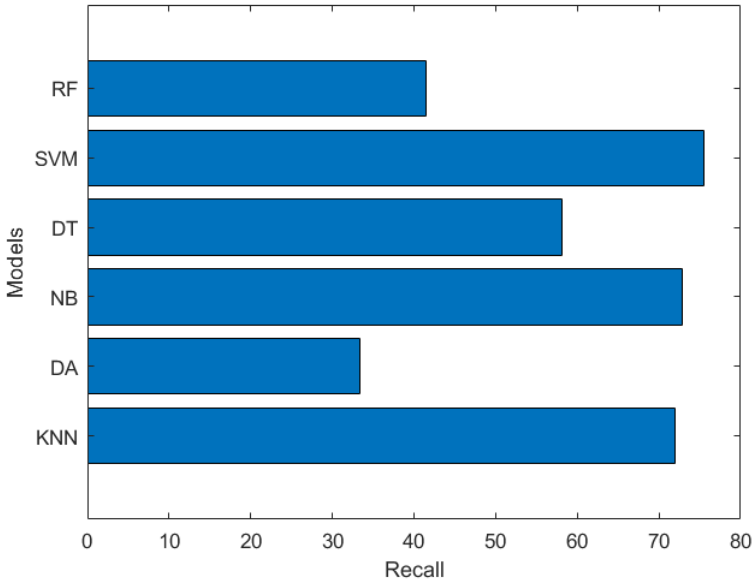

Figure 5.13: Recall for Median Filter

In the Figure 5.13, a horizontal bar graph is representing the recall of different algorithms for median filter.

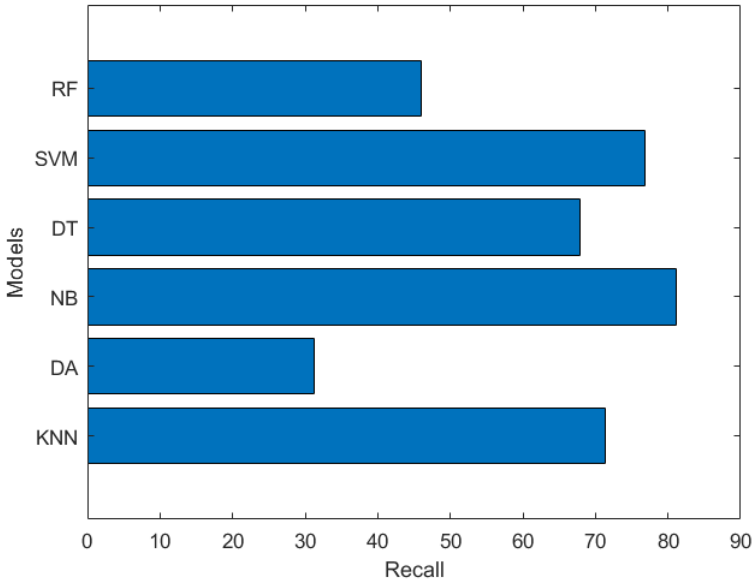

Figure 5.14: Recall for Moving Average Filter

In the Figure 5.14, a horizontal bar graph is representing the recall of different algorithms for moving average filter.

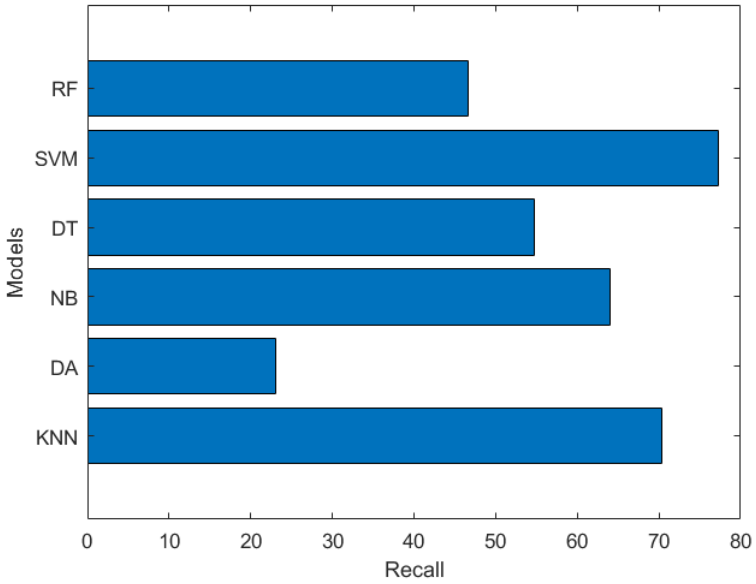

Figure 5.15: Recall for Moving S-Golay(1,7) Filter

In the Figure 5.15, a horizontal bar graph is representing the recall of different algorithms for s-golay(order 1, frame size 7) filter.

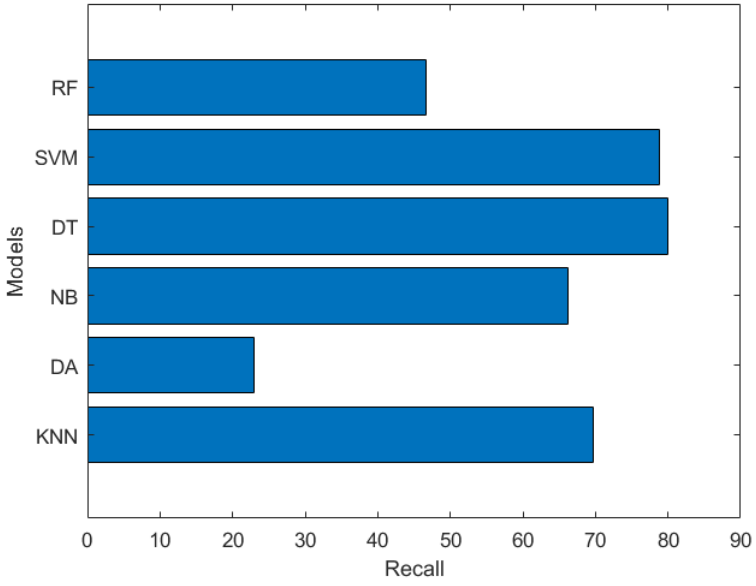

Figure 5.16: Accuracy for S-Golay(2,13)Filter

In the Figure 5.16, a horizontal bar graph is representing the recall of different algorithms for s-golay(order 2, frame size 13) filter.

5.5 ROC(Receiver Operating Characteristic Curve)

An ROC(receiver operating characteristic curve) curve is a graph that shows performance of a classification model at all classification thresholds. This curve plots two parameters:
1. True positive rate
2. False positive rate
True Positive rate(TPR): It is a synonym for recall and so,

$$TPR = \frac{TP}{(TP + FN)} \tag{5.4}$$

$$FPR = \frac{FP}{(FP + FN)} \tag{5.5}$$

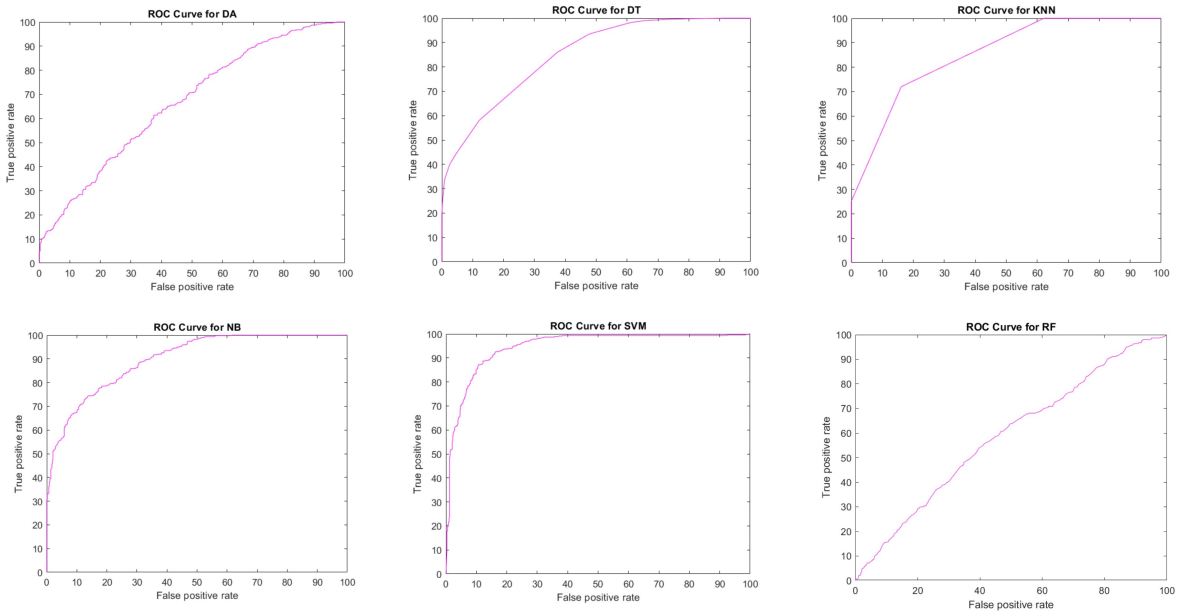

Figure 5.17: ROC for Different Classification Algorithm for Median Filter

In the Figure 5.17, we can see receiver operating characteristic curve for different algorithms for median filter.

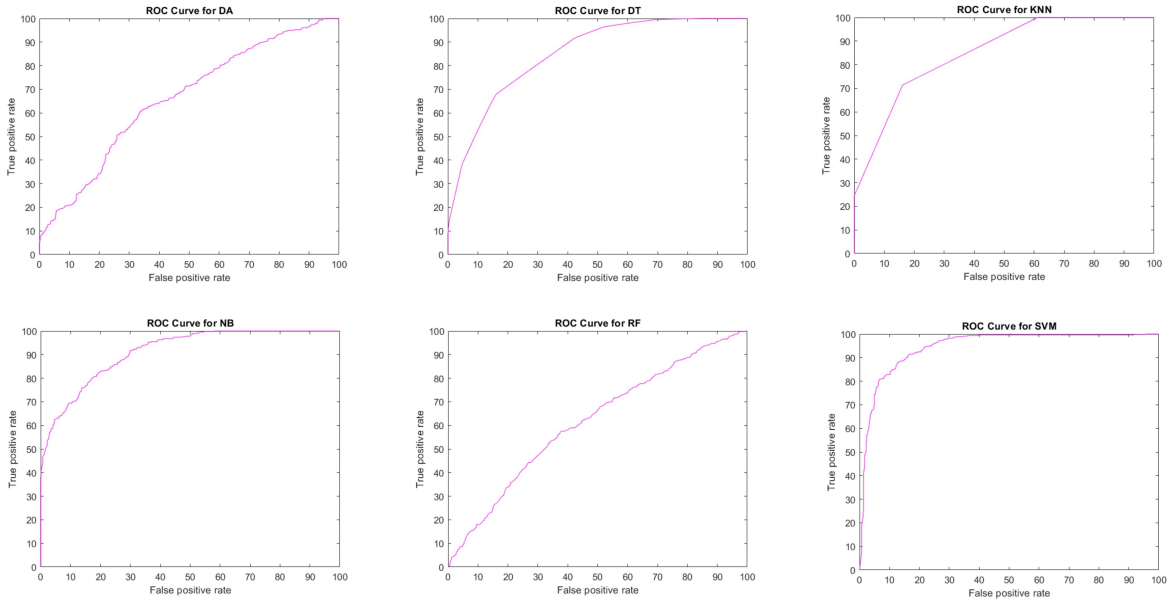

Figure 5.18: ROC for Different Classification Algorithm for Moving Average Filter

In the Figure 5.18, we can see receiver operating characteristic curve for different algorithms for moving average filter.

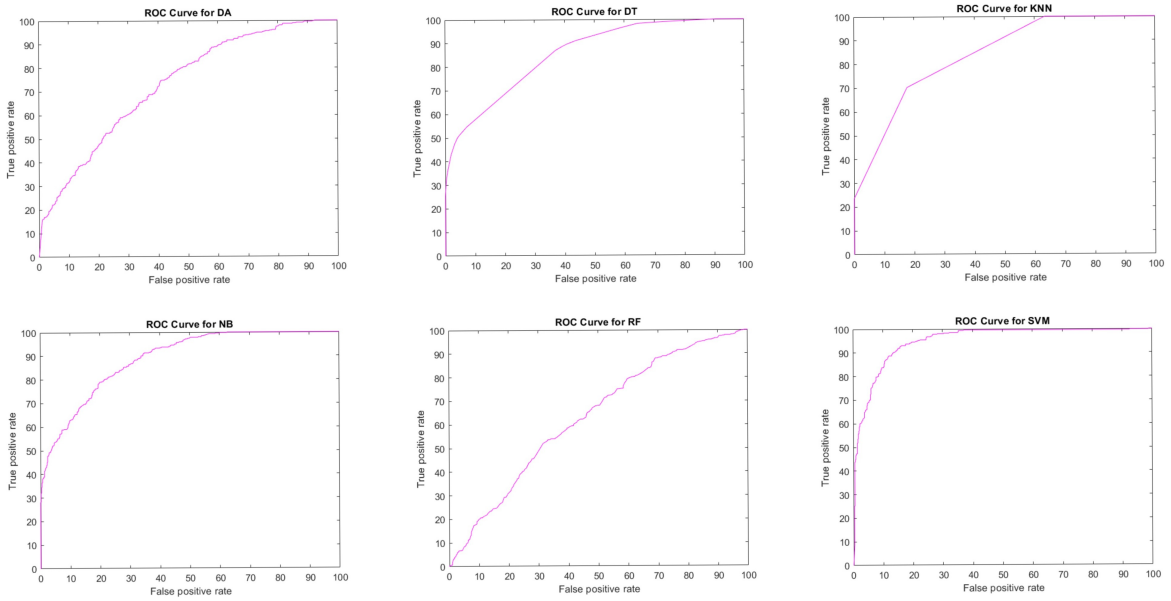

Figure 5.19: ROC for Different Classification Algorithm for S-Golay(1,7) Filter

In the Figure 5.19, we can see receiver operating characteristic curve for different algorithms for s-golay(order 1, frame size 7) filter.

5.6 Specificity

Specificity measures the proportion of negative predictions that are correct. In our model, higher specificity implies model's strength to correctly predict that consumer will not like the product. A tabular representation of specificity for different algorithms based on the filtering method is provided in Table 5.6.

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	83.904	82.534	81.336	83.904	94.521	71.062
Moving Average Filter	71.367	31.236	81.128	67.896	76.79	45.987
S-Golay (1, 7)	82.363	94.521	88.87	92.808	92.808	71.233
S-Golay (2, 13)	81.849	95.377	89.384	79.795	93.151	68.322
S-Golay (3, 59)	68.322	94.349	85.788	84.418	94.692	71.233

Table 5.6: Specificity of different algorithms based on filtering method.

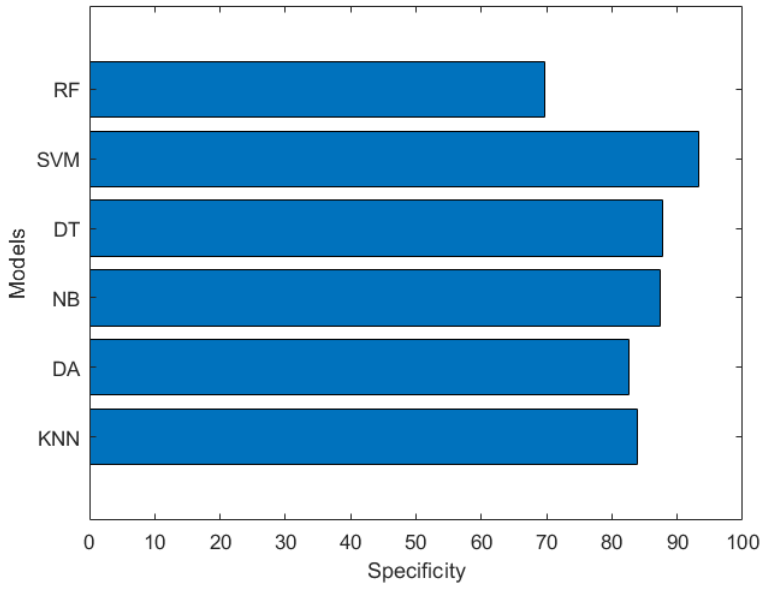

Figure 5.20: Specificity for Median Filter

In Figure 5.20, a horizontal bar graph representation of Specificity for different algorithms for median filter is shown.

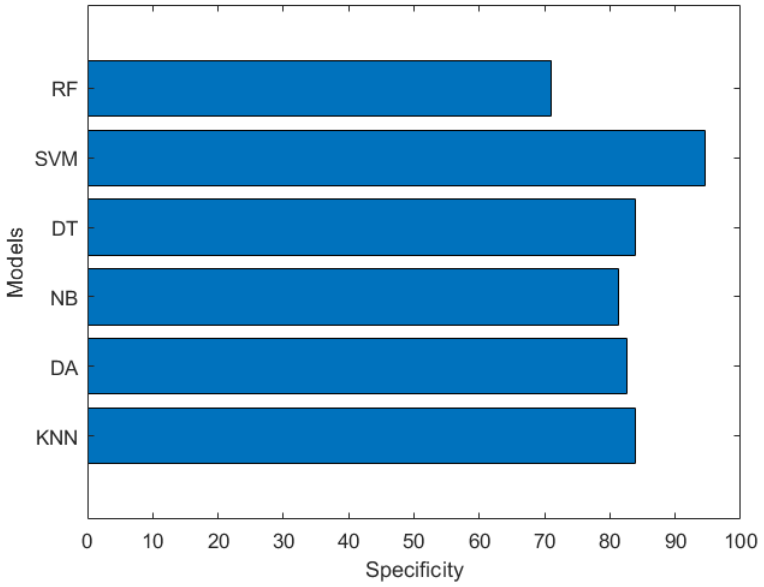

Figure 5.21: Specificity for Moving Average Filter

In Figure 5.21, a horizontal bar graph representation of Specificity for different algorithms for moving average filter is shown.

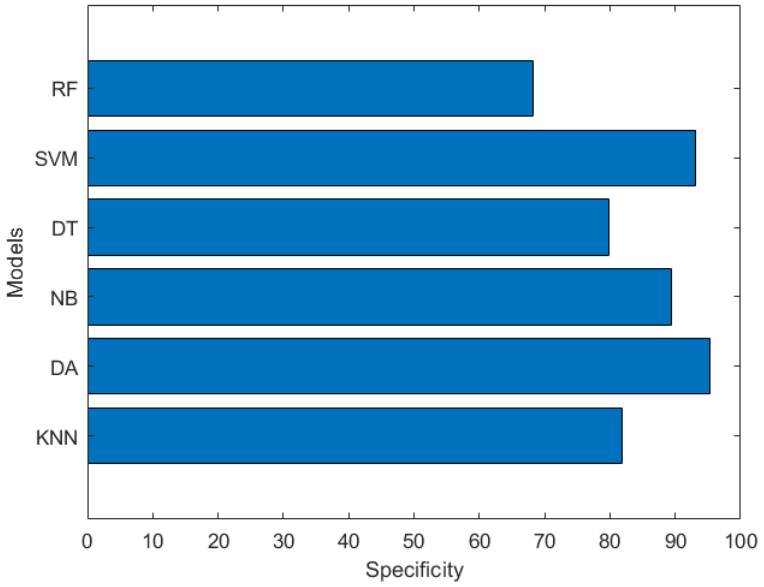

Figure 5.22: Specificity for S-Golay(order 1, frame size 7) Filter

In Figure 5.22, a horizontal bar graph representation of Specificity for different algorithms for s-golay(order 1, frame size 7) filter is shown.

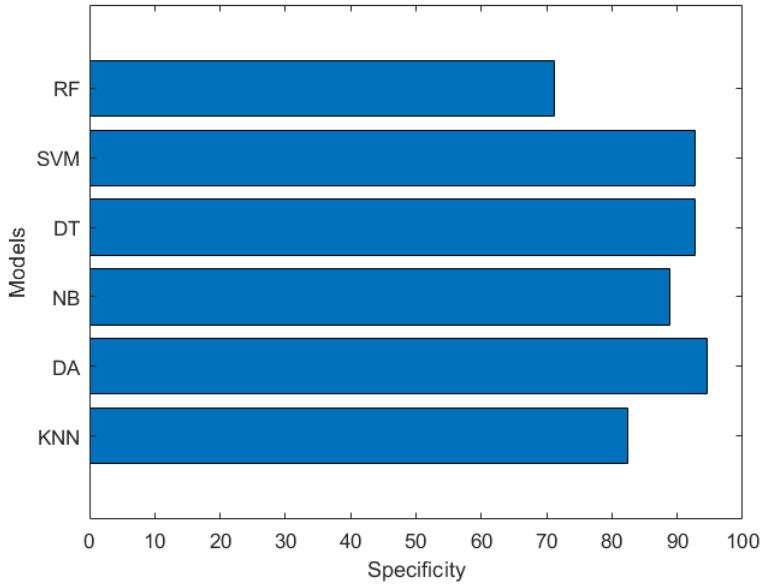

Figure 5.23: Specificity for S-Golay(order 2, frame size 13) Filter

In Figure 5.23, a horizontal bar graph representation of Specificity for different algorithms for s-golay(order 2, frame size 13) filter is shown.

5.7 NPV (Negative Predictive Value)

Negative predictive value measures the probability of a system providing true negative while giving a negative output. A tabular representation of NPV for different algorithms is shown in Table 5.7.

$$NPV = \frac{TN}{(TN + FN)} \tag{5.6}$$

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	79.16	61.09	80.315	71.663	82.827	60.118
Moving Average Filter	78.778	60.325	84.52	76.803	83.763	62.5
S-Golay (1, 7)	77.832	60.86	75.766	72.17	83.771	62.84
S-Golay (2, 13)	77.346	61.075	76.991	83.531	84.735	61.86
S-Golay (3, 59)	77.634	62.33	75.68	75.963	84.816	61.905

Table 5.7: NPV of different algorithms based on filtering method.

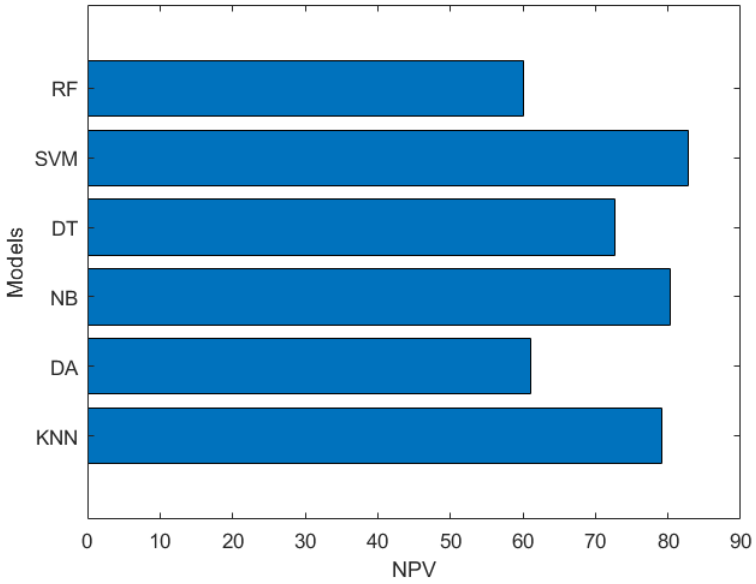

Figure 5.24: NPV for Median Filter

In Figure 5.24, Negative predictive value for different algorithms for median filter is shown in a horizontal bar graph.

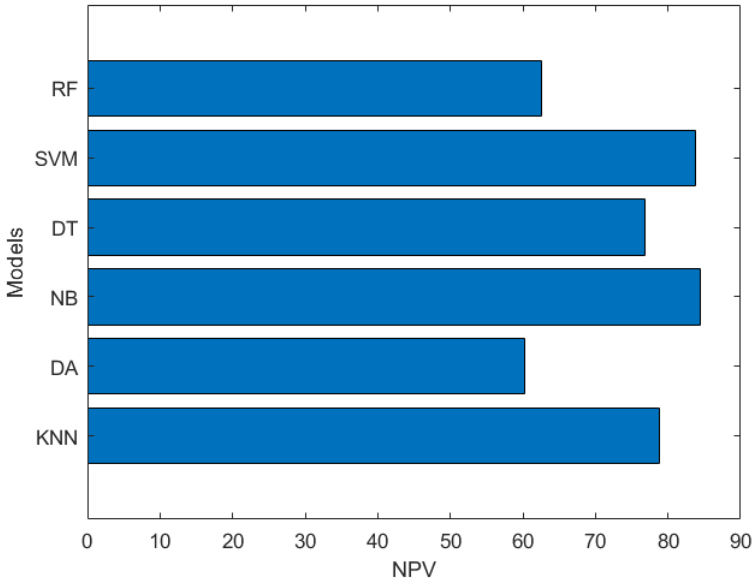

Figure 5.25: NPV for Moving Average Filter

In Figure 5.25, Negative predictive value for different algorithms for moving average filter is shown in a horizontal bar graph.

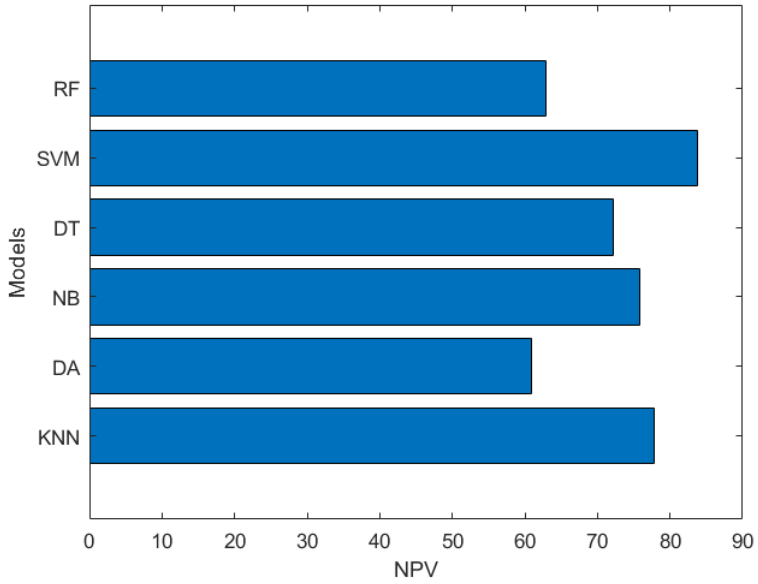

Figure 5.26: NPV for S-Golay(1,7) Filter

In Figure 5.26, Negative predictive value for different algorithms for s-golay(order 1, frame size 7) filter is shown in a horizontal bar graph.

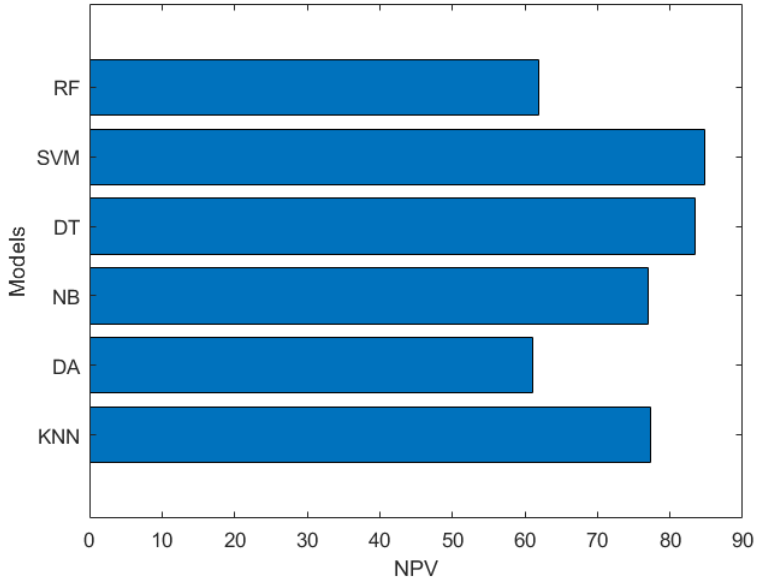

Figure 5.27: NPV for S-Golay(order 2, frame size 13) Filter

In Figure 5.27, Negative predictive value for different algorithms for s-golay(order 2, frame size 13) filter is shown in a horizontal bar graph.

5.7.1 F-Score

F-Score is a matric that combines both precision and recall to evaluate the overall accuracy of a model. It is also called F1-score. In Table 5.8, a tabular representation of f-score is given for different algorithms based on the filtering method.

$$F1 = 2/(1/recall) * (1/precision) \tag{5.7}$$
$$= 2 * [(precision * recall) + (precision + recall)] \tag{5.8}$$
$$= TP/[TP + 0.5(FP + FN)] \tag{5.9}$$

Classifiers	KNN	DA	NB	DT	SVM	RF
Median Filter	74.859	42.957	77.153	67	82.075	46.08
Moving Average Filter	74.434	40.736	79.237	72.12	83.589	50.356
S-Golay (1, 7)	72.973	35.392	71.864	66.755	82.887	50.948
S-Golay (2, 13)	72.297	35.69	73.671	77.848	84.028	49.942
S-Golay (3, 59)	72.666	41.158	71.09	71.179	84.778	49.161

Table 5.8: F-Score of different algorithms based on filtering method.

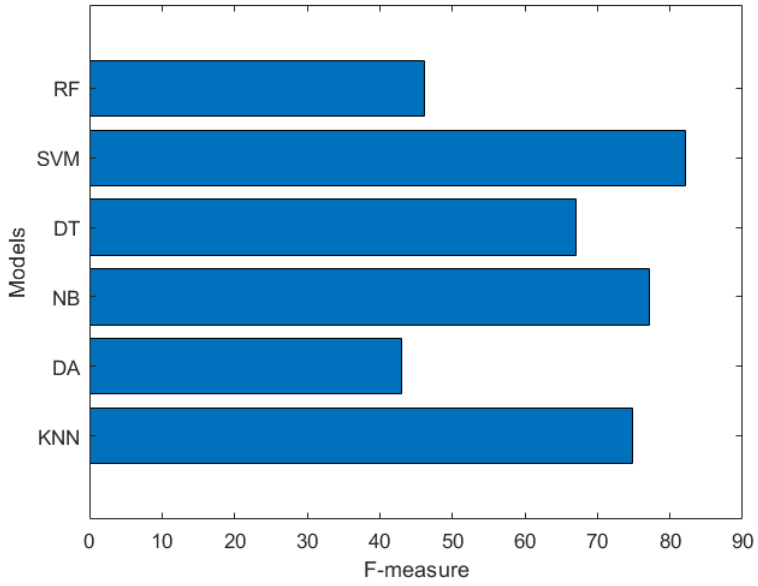

Figure 5.28: F-Score for Median Filter

In Figure 5.28, F-score for different algorithms for median filter is shown in a horizontal bar graph.

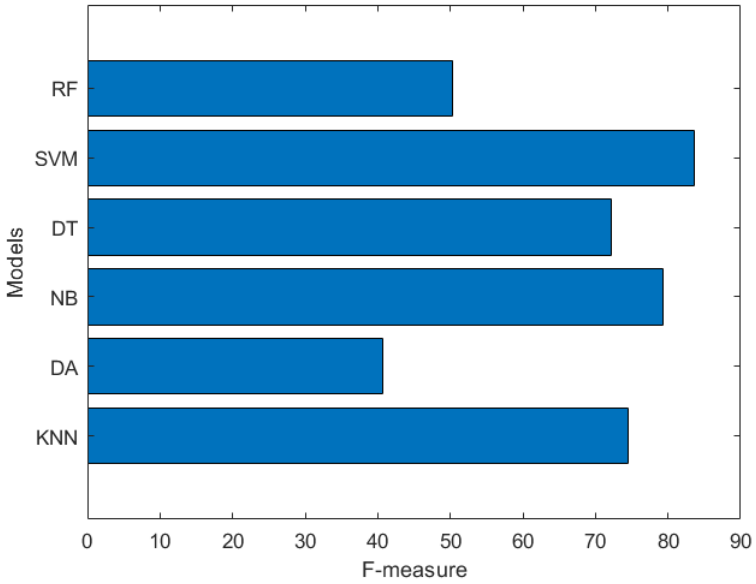

Figure 5.29: F Score for Moving Average Filter

In Figure 5.29, F-score for different algorithms for moving average filter is shown in a horizontal bar graph.

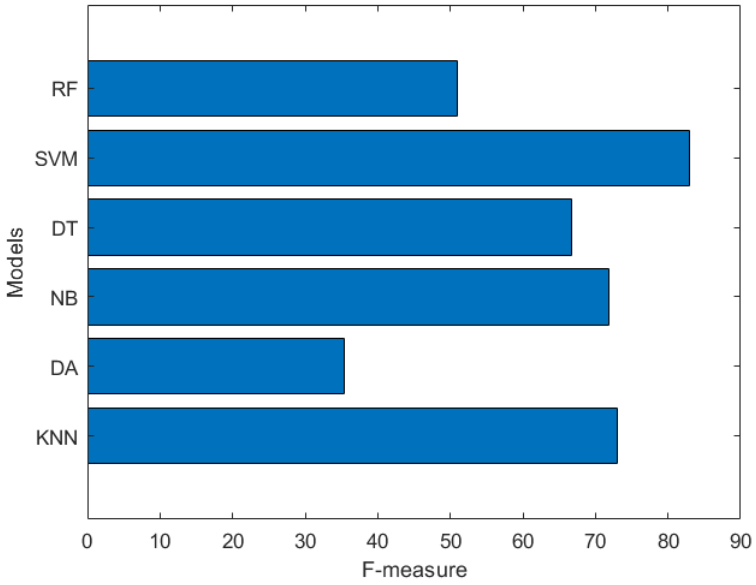

Figure 5.30: F-score for S-Golay(order 1, frame size 7) Filter

In Figure 5.30, F-score for different algorithms for s-golay(order 1, frame size 7) filter is shown in a horizontal bar graph.

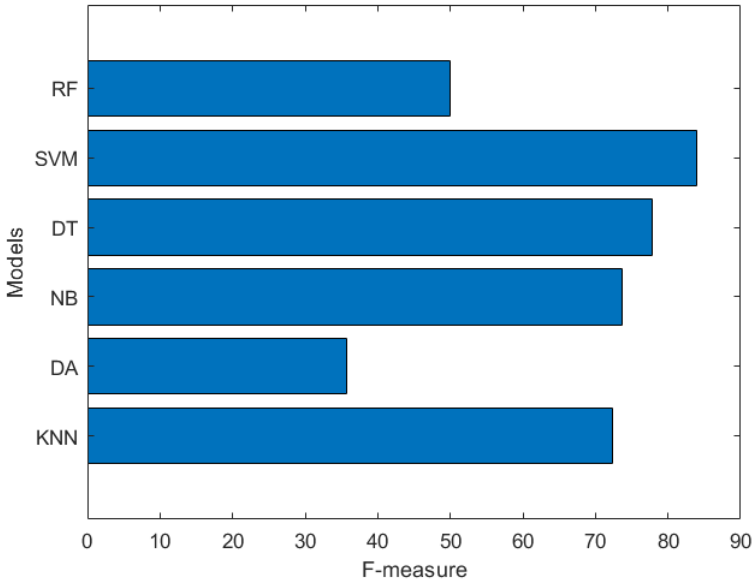

Figure 5.31: F-score for S-Golay(order 2, frame size 13) Filter

In Figure 5.31, F-score for different algorithms for s-golay(order 2, frame size 13) filter is shown in a horizontal bar graph.

5.8 Comparison With Previous Works

In Table 5.9, we presented a comparison between our proposed model and existing work on the same data-set.

Author	**Analysis Method**	**Prediction Rate**	**Imaging Tool**
Mahendra et al. [[21]] 2017	HMM	70%	EEG
Proposed Model 2020	SVM	87%	EEG

Table 5.9: Comparison with previous work.

Chapter 6

Conclusion

In this research work we analyzed EEG signals to get better understandings of consumer behaviour, choice, preference. We tried to build a tool which can successfully predict consumer's choice. We applied different machine learning approaches and proposed a methodology where we acquired accuracy of 86We have also used different filtering methods to determine the changes in results to understand which filtering method works better. Neuromarketing is a relatively new concept. There are a lot of scopes for improvement in this sector. Functional Magnetic Resonance Imaging(fMRI) is also being used to detect brain activities. We have plans to work on facial expression analysis alongside EEG analysis. For example, we can record video data along with EEG data and analyze them separately. We could analyze facial expression from the video data. That could help us detect focus loses of the participants which would help us clear out bad data. Also, if we could merge the results of facial expression and EEG analysis, we would be able to provide much more accurate predictions. Detection of other factors at play is also possible such as the particular color or structure consumers are attracted to and so on. This work will be able to help the advertisers and companies to get a better understanding about their products and consumers and plan their strategy accordingly. Neuromarketing could very well be the next big step in understanding consumer preferences.

6.1 Future Plan

We have plans to integrate facial recognition to analyze the emotion of the participants. We can detect if a participant likes a particular product or not by analyzing facial detection data. Integration of facial recognition capabilities with EEG analysis will provide much more accurate results. In that case, we will use a separate dataset where facial detection data will be recorded along with EEG signals. The system will then analyze the facial detection and EEG data to provide predictions. Integration of facial detection will also help detecting focus loss of the participants which results in bad EEG data. This was an issue with most of the work related to EEG analysis that we will try to resolve in our work.

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