MARKER-LESS AUGMENTED REALITY INTERACTIVE FURNITURE LAYOUTING

Dambagaskumbure Gedara Thilina Krishantha Jayathilaka

(IT13016630)

Bachelor of Science Special (Honours) Degree in SE

Department of Software Engineering

Sri Lanka Institution of Information Technology
Sri Lanka

October 2016

MARKER-LESS AUGMENTED REALITY INTERACTIVE FURNITURE LAYOUTING

Dambagaskumbure Gedara Thilina Krishantha Jayathilaka

(IT13016630)

Dissertation submitted in partial fulfillment of the requirements for the B.Sc. Special Honours Degree in Software Engineering

Department of Software Engineering

Sri Lanka Institution of Information Technology

October 2016

DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to Sri Lanka Institute of Information Technology the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:

The above candidate has carried out research for the B.Sc. Special (Hons) degree in SE Dissertation under my supervision.

Signature of the supervisor: Date

Mr. Udara Samaratunge

ABSTRACT

Designing and marketing furniture exactly according to customer’s specifications always been a common problem in furniture industry causing an irreversible mistake to major loss for the business. In customer’s perspective once they place order, they are unaware of the finished furniture until it arrives their destination. The expectations of the customer may differ across the color, design and scale of actual product they have received, resulting in monetary loss and dissatisfaction.

The research is mainly focused on studying how an efficient suggestion algorithm can be developed using image processing techniques to overcome the problems cause in furniture marketing industry while maintaining improved customer satisfaction and higher business value. The approach involves in color clustering, color identification and furniture suggestion methodologies which can be extended to applications like robotic color detection and computer vision color identifications.

Furniture industry is a growing industry in Sri Lanka. But yet no proper marketing strategy has been implemented within Sri Lanka to compete with challenging global market. In an age where color image processing and augmented reality technologies widely utilized in marketing, multimedia and computer vision applications, this research paper discusses an approach involving digital image processing and augmented reality technologies to overcome the problems caused during marketing. The algorithm was developed and tested using Visual studio 2015. A set of images with different color values were used for analysis of the algorithm and the performance results were 93% accurate.

Keywords: Suggestion algorithm, Image processing, Color clustering, Color identification, Augmented Reality, Computer vision

ACKNOWLEDGEMENT

I would like to express my special thanks of gratitude to our project supervisor, Mr. Udara Samaratunge for his patient guidance, and useful critique of our research work. His willingness to give his time so generously has been very much appreciated. Especially mentioning the moral support and the continuous guidance by providing important feedback enabled us to complete our work successfully. I would also like to thank our lecturer in-charge, Mr. Jayantha Amararachchi for constantly providing us with the guidance and assistance to carry out the research successfully. Also I would like to thank my research group members as well as all the other friends who supported me and encouraged me throughout this project.

Finally I would like to express my special thanks to my parents for their support and encouragement throughout my studies.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
API	Application Programming Interface
AR	Augmented Reality
ASI	Annual Survey of Industries
EF	Entity Framework
HSPA	High Speed Packet Access
HTTP	Hyper Text Transfer Protocol
SQL	Structured Query Language

1 INTRODUCTION

1.1 Background Context

The marketing industry grows and mature day by day with invent of new technologies and marketing concepts that improves customer satisfaction allowing a specific business organization to be ranked at the top of its competitors. With the invent of modern augmented reality (AR) and virtual reality technologies researchers are starting to discover the capabilities of those emerging technologies towards the advancement of marketing industry which will gain a progressive competitive advantage over others. Although number of marker-based augmented reality applications are available, applications developed with marker-less augmented reality technology are small in number as a result of novelty and highly evolutionary nature of the AR technology. By taking the above facts into consideration further studies on how augmented reality, image processing and voice recognition techniques can be used for the advancement of the furniture business industry will provide a better guidance even for other business marketing industries.

According to the statistics provided in annual survey of industries (ASI) [1] which is carried out by the department of census and statics in Sri Lanka, furniture production industry is a stable industry having weightage of 0.8/100 from total productions within a year which is more than the production of machineries, electronics and leather related products in Sri Lanka. With the help of new marketing strategies like augmented reality, the furniture industry can be improved causing the maximum customer satisfaction. Figure 1.1.1 shows the annual industrial production data of Sri Lanka.

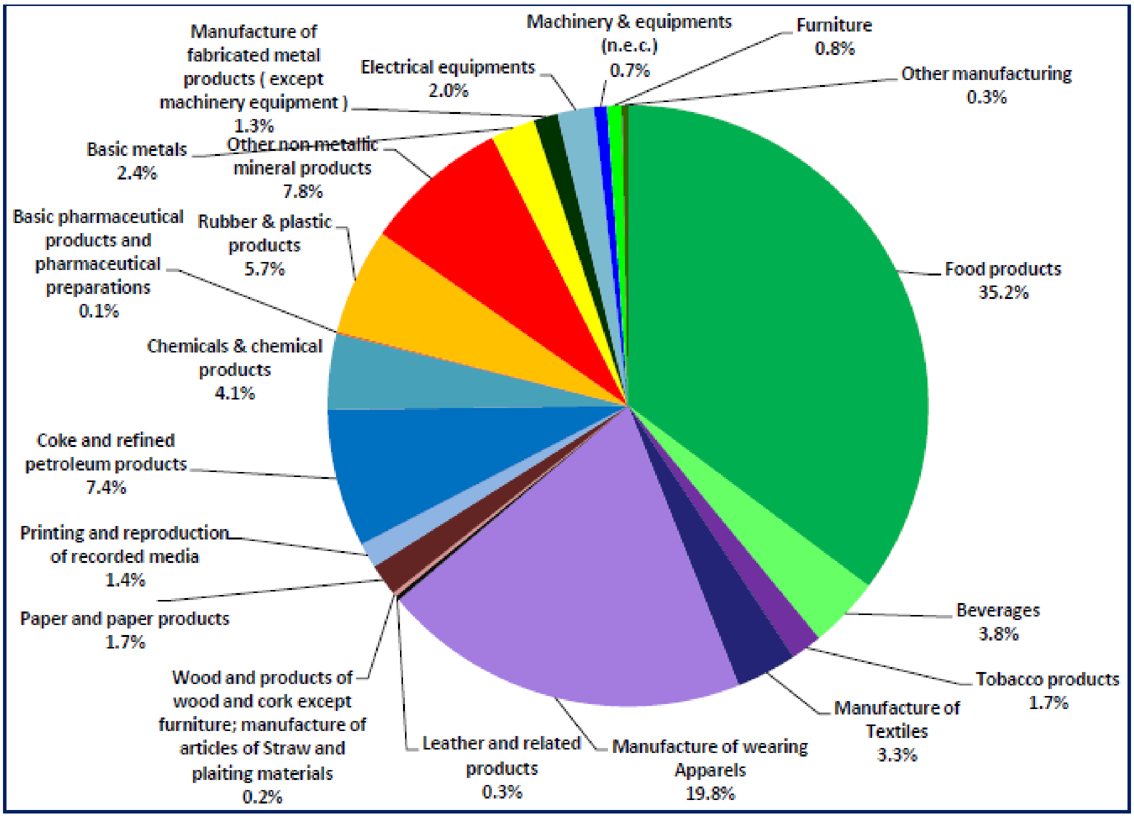


Figure 1.1.1: Statistic data of annual production in Sri Lanka

Source: Report on Index of Industrial Production, 2016- first quarter. Sri Lanka.

1.1.1 Literature survey

Augmented reality (AR) is a rising technology in twentieth century and now it has become extremely powerful tool in marketing, presenting and gaming industries that maps computer generated virtual world with the real world surrounding providing the user a perception of mixed reality [2] by allowing interaction with virtual world that projected on to the real world space. Above mentioned properties of augmented reality technology can be utilized to visualize the products in furniture industry as a mixed reality experience by the users.

The studies of augmented reality further divided into two technological approaches as marker-based augmented reality and marker-less augmented reality. Marker-based technology augment computer generated virtual objects on top of predefined markers. As a result, the performance of AR application strongly rely on the tracking algorithms used in AR [3]. The figure 1.1.2 shows how marker-based augmented reality works where the object is projected on top of a predefined marker by recognizing the patterns of the marker

Figure 1.1.2: Demonstration of marker-based augmented reality

Source: http://www.multidots.com/augmented-reality/

Marker-less AR technology does not rely on predefined markers in projecting virtual objects, rather it uses tracking features and estimation of camera movement [3] ,[4] in order to identify the real world position that the object need to be augmented. The main algorithm in marker-less AR support estimation of orientation, position and 3D movement of the camera using the images obtained during the environment tracking [3]. The figure 1.1.3 shows how marker-less augmented reality works by placing a rabbit on the user's palm while maintaining proper orientation of the rabbit even if user moves hand in real world, allowing the rabbit also move along with the hand.

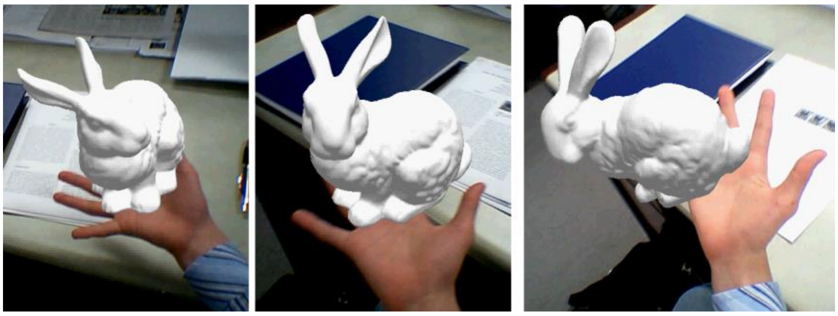


Figure 1.1.3: Demonstration of marker-less augmented reality

Source: https://ilab.cs.ucsb.edu/index.php/component/content/article/10/25

AR technology use advanced image processing techniques in achieving its objectives. The basic objectives of an AR system [5] can be listed down as follows.

1. Blend real world and virtual world.
2. Real-time interactions
3. Registration in 3D world space (accurate alignment of virtual objects with real objects)

The difficulty in blending with real world is an existing problem in augmented reality as the human factors and cognitive science [6] directly affect to the effectiveness [5] of the final outcome. Researches about Global illumination can be considered as a partial solution for the poor blending problems in AR systems. Within the context of global illumination, environmental colors plays a major role in approximating the illumination and absorption factors. Similar image processing techniques can be utilized in order to assist users by suggesting furniture arrangements based on interior design guidelines. Furniture placement is challenging as it requires variety of visual and functional criteria [7]. Throughout this research we use color matching as the primary objective in providing furniture suggestions to maintain a better visually balanced composition in furniture placement.

Color is a visual perception in humans [8] which derives from the light spectrum by stimulating the nerve cells or the receptors located in human eyes. The sector corresponds to the visible light in the electromagnetic spectrum also called as visible spectrum forms due to the emission of protons with different wave lengths as a result of the radiation emitted by the sun. The visible spectrum ranges from 390 nm to 700 nm [9] relevant to wavelength in the electromagnetic spectrum and have no distinguishable separation between two consecutive colors.

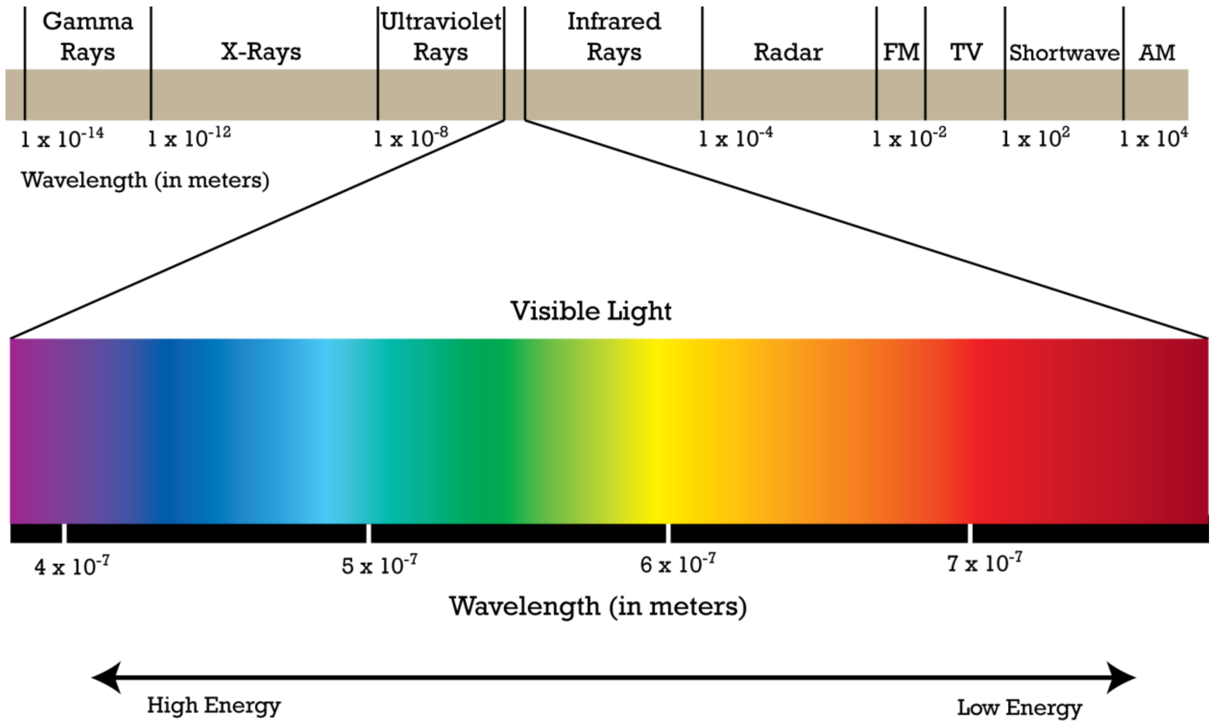


Figure 1.1.4: Electromagnetic spectrum and visible light

Source: http://www.pion.cz/en/article/electromagnetic-spectrum

However, all the colors that can be distinguish by the human eye are not present in the light spectrum itself. The colors present in color spectrum are known as pure colors and the absent colors which they formed by mixing multiple wavelengths of pure colors are known as unsaturated colors.

Human eye is the main organ that is sensitive to the colors and light present in the environment which has object isolation and identification capabilities. When light beam falls on an object, it absorb light by a fraction and non-absorbed light is reflected back to the environment. The reflected light moves through the cornea of the eye and falls on the eye lens. The eye lens controls its own curvature by the help of ciliary muscles present in the eye to form an inverted image on the retina, located on the rear surface of the eye ball. Retina is consist of photosensitive rod and cone cells which transmit the formed image to brain by transforming it to series of electrical signals. There are approximately 6 million cone cells in retina [10] which are sensitive to brightness in the environment. Cone cells become active during high brightness levels and allow color perception in vision. Although the approximate count of rod cells is 125 million, they become active only in low light condition allowing night vision.

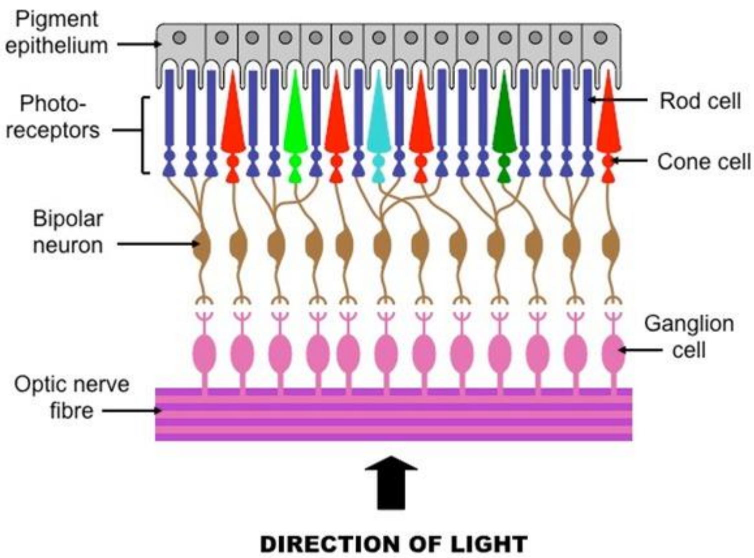


Figure 1.1.5: Structure of retina in eye

Source: https://orangesdms.wikispaces.com/Rod+Cells+-+NK

The color is a powerful descriptor when it comes to representation of certain idea to the people, allowing them to distinguish and isolate certain objects from the background. Although the process of identifying certain colors by human brain is psychological, the nature of color can be expressed by formal experimental results described in [11]. Basically what human define and perceive as the color is the nature of the light reflected back by an object when white light incident on that object according to [11]. Also the experience of color in objects not only depend on the local light reflected from each object, but instead depends on relative light across the entire scene [12] visualized by the user.

Nature of color depends on three important characteristics: radiance, luminance and brightness [11]. Radiance is the amount of light emitted by a light source and measured using Watt (W). Luminance is the light perceived by the object being viewed and usually measured in Lumens (lm). The last factor affects to color perception which is brightness is a subjective measure that depends on each person separately. But, still brightness and illuminance plays an important role in color perception. For surface illumination of an object to be useful in object identification, the color of the object should be relatively stable through its environment. This phenomenon of stability is known as color constancy [13]. Achieving color constancy is a difficult problem because the sensory signal that reach the eye from the scene is a collection of both light reflected from the object and the illumination that reflect back by the environment where the object is placed. However, most of the common day-today tasks related to color are a process that requires to identify objects in the environment rather than making appearance matches [14]. In that case the observer consider the reflectance factor of the object rather than the appearance in the scene. The figure 1.1.1.5 demonstrates the Adelson’s checker shadow [15] where the square marked with “B” looks lighter than the square marked with “A” due to the shadow of the cylindrical object. But in reality both squares are filled with the same color. This is an example to show that the characteristics of colors in the background directly affect the color of the object in the scene.

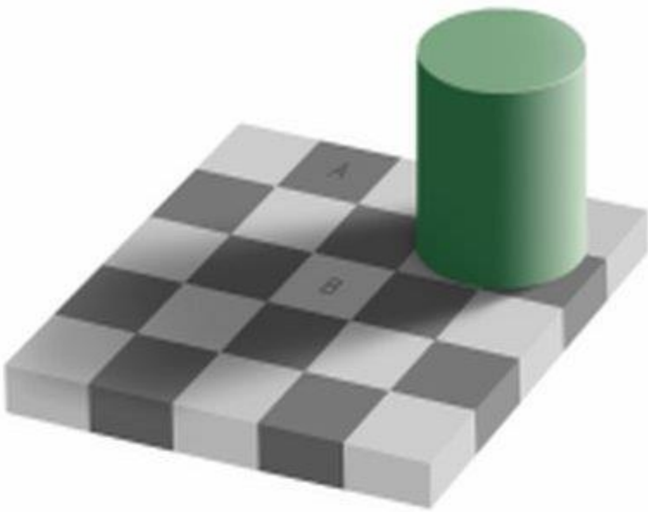


Figure 1.1.6: Adelson’s checker shadow

Source: http://web.mit.edu/persci/people/adelson/checkershadow_illusion.html

Each and every people is affected differently by certain colors in the environment due to color characteristics and individual human behavior. However the effect is different from one person to another depending on the gender, living environment, age group and cultural influences [16]. Color psychology is a widely used for marketing and business industries in order to influence customers' emotions through the services and goods provided by the business.

The "Placebo effect" [17] is well known for the usage of color psychology in the marketing industry where researchers has discovered that the placebo effect is a coordination between mind and the body. The research is conducted on two groups where one group is provided with a "hot colored" pill and the other group provided with a "cool colored" pill while monitoring their biological behavior. The studies confirmed that the group provided with "hot colored" pills had active biological metabolism than the other group even though they are provided with same dosage which only differ from the external color.

Although color is an independent sense, the preference for a color depends on several factors as studies of the past researchers. Sensory Psychological approach by Hurlbert and Ling [18] discovered that the color psychology depends on the gender as neural cells located in human retina differently specialized for males and females in "Hunter-Gather" societies. Ecological Valance Approach [19] shows that the color psychology depends on the colored environmental objects rather than the gender. According to Ecological Valance Approach the individual's color preference is determined by the color of the environmental objects present at a particular time. The researches in the domain of color identification [20],[21] mainly use RGB value averaging using MATLAB tool to identify colors and does not incorporate any clustering algorithm to identify closely related colors. Figure 1.1.6 shows the relationship between the colors and the human psychology.

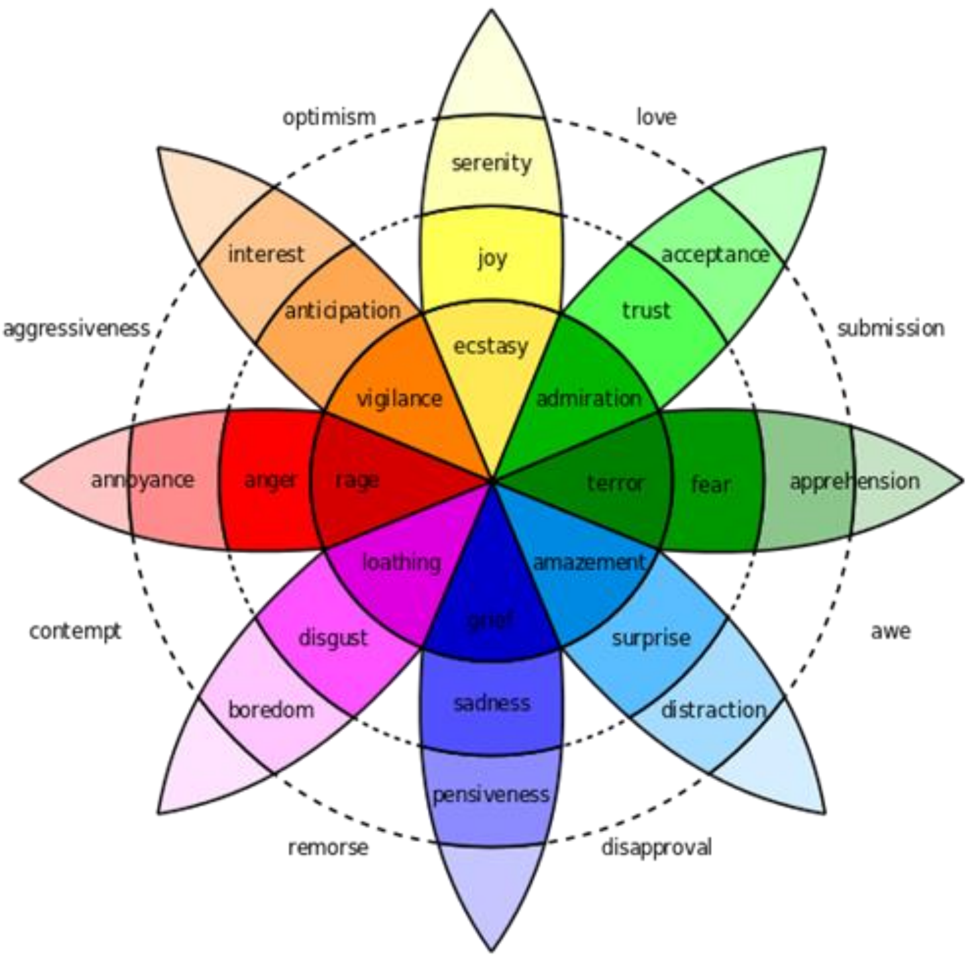


Figure 1.1.7: Relationship between colors and psychology

Source: https://en.wikipedia.org/wiki/Contrasting_and_categorization_of_emotions

Since the color preference is highly affected by the objects in the environment, certain business use colors to suggest business items that match the user preferences by altering the user's emotions [22].

In order to provide user with furniture suggestions depending on existing environmental colors, similar colors in the environment should be clustered by their characteristics. This enables the system to remove presence of duplicate colors in the data set. We have used K-means algorithm, a common clustering algorithm in order to cluster the captured image data in real-time, providing the users the capability of selecting furniture from a categorized sub set of available furniture set. K-Means algorithm is a distance based algorithm often used in unsupervised clustering of data. A distance based metric should be implemented in order to obtain the clustered results using the K-Means algorithm. The “mark-less furniture layout” application uses the Euclidian distance metric as the technique to find the nearest colors. Distance based metrics are used to measure the similarity between the data items. In clustering algorithms, distance based metrics plays a major role in obtaining, categorizing and defining distance between data items according to weighted metrics. Euclidian distance, Manhattan distance and Chebychev distance are the commonly used metrics in clustering algorithms [23].

Existing products with related to the furniture industry that allow customer to augment and get real time furniture suggestions can be rarely identified in the global application market.

- “Sayduck” application
  Sayduck [24] is an application developed for both iOS and android devices using Vuforia [25] framework enabling the customers to try out furniture products virtually while customizing them. But the application does not support the active furniture suggestions, marker-less AR and voice command features which will be value added services in making the customer satisfaction ratio high.

- “Augmented furniture” mobile application
  Augmented furniture [26] is marker-based application where the user need to place a predefined marker in order to augment furniture in the environment. The application is mainly targeted for iOS devices leaving the majority of android users out of their sales. Even though it supports multiple furniture item placement in the augment environment, it does not support scale identification and suggestion features.

- “VIUTEK uDecore” application
  uDecore [27] is a customizable 3D room planner application which utilize augmented reality technology for iOS devices. uDecore can support furniture

models to be customized and placed in a virtual 3D room. A major benefit of the application is that it can work without active internet connection, as 3D furniture models can be permanently stored in device after an initial setup.

- "Augment" mobile application

  Augment [28] make available a large collection of furniture with the help of marker-less AR through a virtual furniture showroom allowing customers to try products at their desired location before purchase. Even though the application consist of advances features like multiple object placement and furniture customization the lacking of features like real time furniture suggestions create a drawback in the application in terms of customer satisfaction.

1.2 Research Gap

Even though several researches has been carried out in the domain of furniture industry in order to maintain better customer satisfaction, no better solution was implemented yet in Sri Lankan furniture marketing industry. Most of the existing solutions provided by the researchers are mainly based on marker-based augmented reality, thus it need additional effort in augmenting furniture to real world. Another fact that should be take into consideration is that the existing approaches provided are highly resource consuming leaving the user to have a high end device rather than a mobile device.

According to the literature survey there exist only limited number of applications that provide real-time furniture suggestions by analyzing the environment of the user. The absence of a suggestion feature in a wide industry like furniture marketing makes it difficult to focus on marketing goals of the business and to compete with other similar business domains.

Considering the above mentioned facts it is clear that there is a clear research gap in this domain that need to be addressed and filled.

1.3 Research Problem

Furniture industry is a rapidly growing industry in Sri Lankan and global market. With the time, the demand for furniture and their design changes rapidly causing the manufacturers to try alternative approaches to increase their profitability while adopting to market changes with help of relevant technological support. This indeed should be accomplished while avoiding costly mistakes and by preserving limited resources available. The proper marketing is a key pillar of increasing the profitability in a business which add higher values for goods throughout the supply chain.

Considering about the proper marketing strategies, Sri Lanka is lagging behind the global market status, in the context of furniture industry. Designing a furniture exactly according to customer specifications will be a complicated task for the designers and a mistake will cause costly financial loss for the business. In customers perspective after they placed the order, they have no idea about the finished furniture until it arrives their destination. The expectation of the customer may be differ with the actual product they have received causing them a monetary loss. This scenario often can be seen in custom made furniture rather than ready-made furniture. Even with the ready-made furniture the problem exist, though is not as large as with custom furniture. The existing approaches in selling and purchasing furniture cause poor customer satisfaction as well as drop in the profits of the business.

Another major problem face by an end customer is difficulty in choosing a furniture matching their environment due to lack of knowledge in interior home designing. As general human nature, customer's mind become bias towards different items when provided with large number of items, even if they are not matching their specifications. Still the perception of colors depends on the background colors present in the environment causing them to trick their mind. Even though this problem arise due to confusion in human mind, it is technically cause due to lacking of proper suggestion system in the field of furniture marketing in Sri Lanka.

In this research we address the above mentioned problems and provide a solution to overcome them while maintaining higher customer satisfaction and business goals.

1.4 Research objectives

1.4.1 Main Objectives

Project “Mark-less augmented furniture layout” has focused on border range of objectives in order to maintain proper customer satisfaction towards the furniture industry. Thus to increase the profitability in the furniture business. The team came up with following general objectives of the “Mark-less augmented furniture layout” application by considering the above known factors.

- Provide customers with real time furniture suggestions matching their environment.
- Allow customers to place furniture in an augmented world.
- Allow customers to customize a selected furniture according to their desires.
- Provide ease of customizing furniture using voice recognition features.

1.4.2 Specific Objectives

Taking the above mentioned general objectives into consideration the team came up with a set of more specific features that need to be addressed in order to achieve each general objective

Related to suggestions

- Use of efficient algorithms and best technologies to identify the prominent environmental colors in user’s surrounding.
- Enhance the environmental colors in captured image to reduce the lighting issues when analyzing environmental colors.
- Provide customer with relevant furniture suggestions based on the identified environmental colors.
- Allow customer to filter the furniture according to desired patterns.
- Provide a way to augment filtered furniture, view details and a method that facilitate to contact with the furniture dealer.

Related to augmentation

- Identify the latest and best technology to provide augmented reality experience through mobile device
- Implement furniture augmentation with identified technology allowing customer to maintain and control the position and orientation of the furniture.
- Implement features to provide customer the power of customizing furniture.

Related to voice recognition

- Allow customers to customize an augmented furniture through voice commands.
- Provide a description of a selected furniture (text to voice) through audio channel.

Related to scale identification

- Determine the scale of the real world and augment furniture according to the identified scale.

2 METHODOLOGY

2.1 Approach

Mark-less augmented furniture basically focused on increasing customer satisfaction while providing increased benefits to the business. Series of procedures have been followed in order to achieve the general objectives of the system, which will be describing in this chapter.

Requirement gathering is the initial step followed during the process in achieving specific goals of the system. The features that should be included in the system are identified through reviewing existing applications and studying on researches carried out in the domain. With the gathered requirements the next step was the designing of suitable architecture of the system.

As the web and networked applications become more and more important, the importance of selecting a proper database management system also increases. Database server is a computer program that provides services related to database management to other computers and systems. Microsoft SQL server management which is a rational database management system is selected as the best option to develop database for the Mark-less furniture application because of the following benefits it provide.

- SQL server is provided with Business Intelligence (BI) tools and database tuning advisor features which enable easy and efficient scalability of the database.
- Well supported with documentations and can easily be integrated with other Microsoft products.
- Allows efficient XML support and range of connectivity drivers matching all available platforms.
- Provided data recovery support allows to restore the database easily in a failure.

The most important fact under selecting Microsoft SQL server as the DBMS in the application is that it is compatible with Entity framework. Entity framework (EF) is an object relational mapping framework for .NET applications which support data oriented software development. EF provide easy to use, fast LINQ syntax for basic database functions like insert, update and delete where it minimize the required lines of code in accomplishing complex tasks.

Database server should be accessed through a “front end” application running in user’s computer or via a “back end” service which runs on another server computer. Mark-less furniture application uses backend web application programming interface (API) in order to access the cloud hosted database.

API is a set of subroutines, protocols and tools for developing software [29]. It provides the all the basic building blocks for developing software, making the development process easier and faster while governing the communication between intended systems. API achieve the above mentioned characteristics by exposing specific program’s internal functions to outside making it possible to communicate between systems in a platform independent manner while imposing relevant constraints to control the behavior of the communication. Characteristics of a general API can be listed down as below which allows the Mark-less furniture application to modernize its features.

- Increased efficiency
  Providing API access to the business logic reduce the burden in redistributing the updated logic once the API published.

- Wider range of clients
  Published API allows anyone to create presentation tier using any platform that consumes the published API logic. This allows developers to develop systems without knowing the complex business logic of the backend services because of service endpoint like nature in API.

- Easy in automation

  API enables the developers to freely update business logic without affecting the dependent presentation tier logic by automating the process of update propagating mechanisms.

- Integration

  API allows efficient integration with other platforms providing relevant up-to-date documentation information.

Even though there are no any constraints on developers to govern how the connectivity of API and their system should be implemented, several standards have been introduces in order to reduce connectivity issues. APIs that connect via the internet, uses Hyper Text Transfer Protocol (HTTP), a connectivity protocols that provide access to its internal logic through a web browser. Here, the APIs which use HTTP verbs in order to connect with the system are known as “web APIs”. Different HTTP verbs and their general behaviors used in Mark-less furniture application can be listed down as below.

HTTP GET	- Used to request data from the API.
HTTP POST	- Used to submit data to the API.
HTTP PUT	- Used to update resources in the API.
HTTP DELETE	- Used to delete resources in the API.

As mentioned, APIs provide portability of data between different platforms which is a major concern in selecting API technology to develop the Mark-less furniture system. The portability of the API is achieved through technologies like eXtensible Markup Language (XML) and JavaScript Object Notation (JSON). XML and JSON are the two most common data interchange formats used in web application in recent past [28]. But in Mark-less furniture application the developers use JSON as the message format because of the following superior features exist in JSON than the XML.

- The notation and syntax of JSON is much simpler than the XML.
- JSON files are smaller than the XML files having the same content [31].

- The serialization and deserialization of JSON file is faster than XML [32].
- JSON uses less system resources than the XML.

After finalizing the technological requirements, next goal is to identify the methods that can be used to identify colors in the environment through the application. Following sections describes the available technologies and approaches in color representation, image processing, color clustering, distance based suggesting and their validity to Mark-less furniture application.

Understanding about color and representations of colors in different ways is an important factor. As stated earlier in this report, color is a visual perception in humans which derives from the light spectrum and can be represented by different forms of color models. Color models are mathematical representations of colors where the color can be represented by three or four numerical components. Popular color models and their definitions can be list down as below.

2.1.1 RGB Color model

RGB color model is an additive color model, where colors are made by adding different proportions of red, green and blue primary colors together. The nature of the final color depend on the proportions of the red, green and blue colors which superimposed together. In RGB color model zero intensity from each primary colors components generates black color and full intensity from each component generates white color while similar intensities from each component generate a shade of grey. When the proportions are different the result depends on the strongest and weakest intensity proportions of color components. Figure 2.1.1 shows the additive color mixing model of RGB. Figure 2.1.1 also represent that adding red to blue generates magenta, adding blue to green generates cyan, adding red to green generates yellow and adding three colors together generates white.

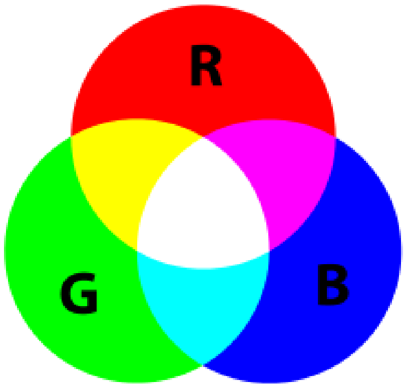


Figure 2.1.1: Additive color mixing model

Source: https://en.wikipedia.org/wiki/Additive_color

Since colors in RGB color model are represented by three color components, it can be visualized in three dimensional color space using a color cube. Each edge and node represents a certain intensity that range from 0 to 1 where 0 represent no intensity and 1 represents full intensity values. Figure 2.1.2 shows the representation of colors in the 3D color space.

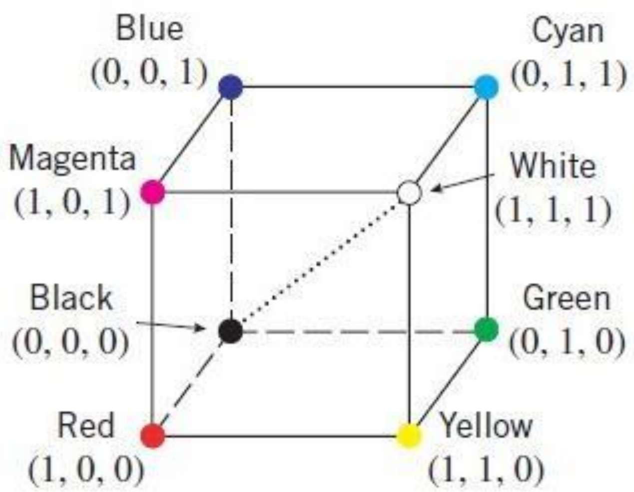


Figure 2.1.2: RGB color cube representation

Source: http://www.blackice.com/colorspaceRGB.htm

RGB color model is commonly used in hardware oriented devices like photography devices and display devices. Each pixel in display devices are a combination of red, green and blue components which are located in close proximity but yet separate from each other, allowing to mix color in different proportions. Even though RGB color models can be used in other applications like printing images, the standard is to use CMYK model in printing as the colors appears differently if printed in RGB.

2.1.2 CMYK Color model

CMYK color model is a subtractive color model, where colors are made by adding different proportions of cyan, magenta, yellow and black secondary colors together. CMYK color model is used in printing purposes and represent the four ink types used in printing. Figure 2.1.3 shows the subtractive color mixing model of CMYK. In CMYK color model zero intensity from each secondary color components generates white color and full intensity from each component generates black color while similar intensities from each (not maximum intensity) component generate a shade of grey. Figure 2.1.3 also represent that adding yellow to magenta generates red, adding magenta to cyan generates blue, adding cyan to yellow generates green and adding three colors together generates black (also known as K or "key" value).

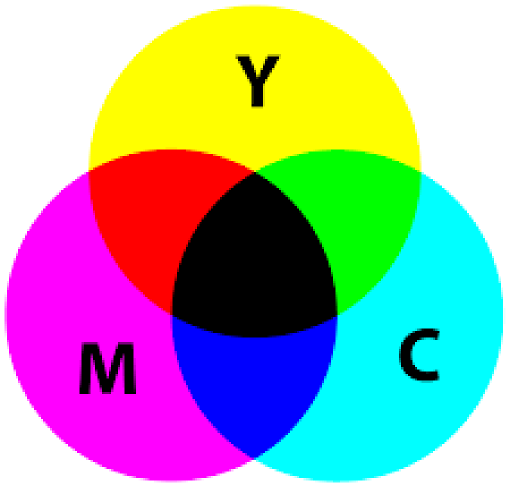


Figure 2.1.3: CMYK color model

Source: https://en.wikipedia.org/wiki/CMYK_color_model

CMYK color model is introduced because the colors we see in a computer display differs when it get printed on a paper as a result of using different color models in display devices and the printers. The main difference between RGB and CMYK models caused due to “colors” and “pigments” which exist in RGB model and CMYK model respectively. In RGB model “colors” represent energy radiated by a luminance object while “pigments” in CMYK model represent the colors that is not absorbed by a certain object like ink which is opposed to “colors” in RGB [33].

2.1.3 HSI Color model

HIS color model is often used in computer vision or image processing application as it represent colors similar to how human eye perceive colors. HIS stands for Hue, Saturation and Intensity properties of the color. The three components hue, saturation and intensity describes the pureness of the color, whiteness of the color and brightness of the color respectively. As RGB model can be represented by a cube, the HSI model can be represented using a color cylinder or a cone. In each cylinder or cone the angle around the axis represent the Hue, the distance from the axis represent the Saturation and the distance along the axis represent the Intensity values [34]. Figure 2.1.4 shows how HIS color model is mapped into a conic shape.

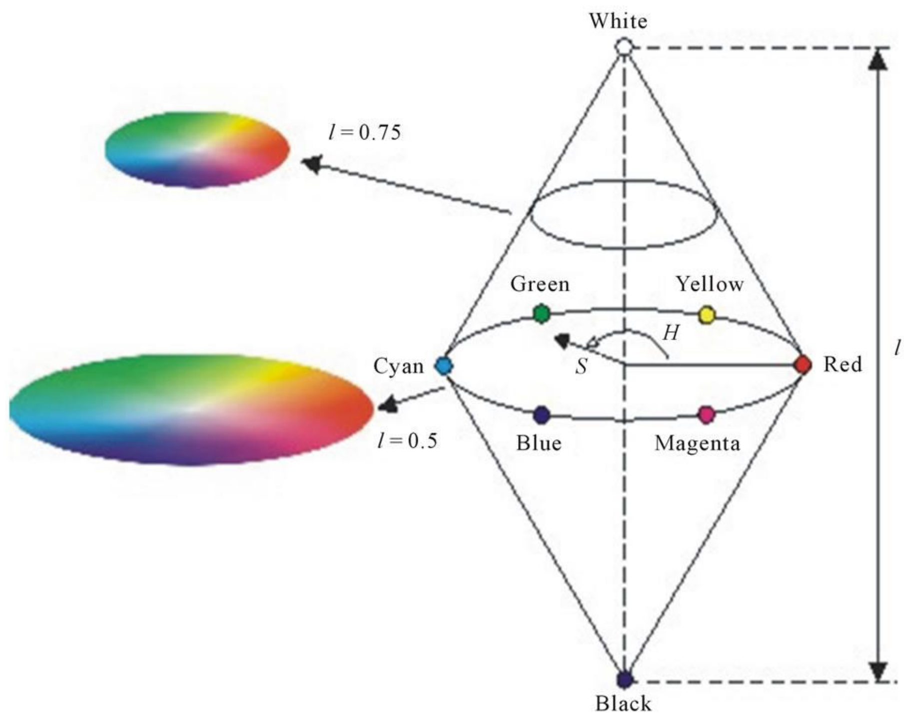


Figure 2.1.4: HSI color model

Source: http://www.blackice.com/colorspaceHSI.htm

HIS color model has better capability in representing human color perception, because human eye can distinguish different hues easily whereas saturation and intensity levels does not affect the color perception largely [35]. Because of the above mentioned fact Mark-less furniture application uses HSI color model to identify colors present in the environment. This cause the general RGB color model to be transformed into HIS color model.

2.1.4 RGB to HSI color conversion

First step begins with normalizing the R, G and B values. “r”, “g” and “b” values represent the normalized R,G,B values respectively.

$$r = \frac{R}{R+G+B} \qquad g = \frac{G}{R+G+B} \qquad b = \frac{B}{R+G+B}$$

Then each H, S and I component values can be calculated using following equations.

$$h = cos^{-1}\left\{\frac{0.5\ .\ [(r-g)+(r-b)]}{[(r-g)^2+ (r-b)(g-b)\ ]^{1/2}}\right\} \quad h \in [0,\pi]\ for\ b \leq g$$

$$h = 2\pi - cos^{-1}\left\{\frac{0.5\ .\ [(r-g)+(r-b)]}{[(r-g)^2+ (r-b)(g-b)\ ]^{1/2}}\right\} \quad h \in [\pi, 2\pi]\ for\ b > g$$

$$s = 1 - 3 * \min(r, g, b) \qquad s \in [0,1]$$

$$i = \frac{(R+G+B)}{3*255} \quad i \in [0,1]$$

Then the calculated h,s,i values converted in the range of [0,360] , [0,100] , [0,255] respectively using following equations.

$H = h * \frac{180}{\pi}$ $\qquad S = s * 100$ $\qquad I = i * 255$

Finding suitable metric for determining the distance between two color points to cluster data is the next step involved in developing Mark-less furniture application. Distance based metrics are used to measure the similarity between the data items and often used in clustering algorithms. Euclidian distance, Manhattan distance and Chebychev distance are the commonly used metrics in clustering algorithms.

2.1.5 Manhattan distance

Manhattan distance, also known as L_1 distance, measure the distance between two vectors in n dimensional vector space. If $x = (x_1 , \ x_2 , .., x_n)$ and $y = (y_1 , y_2 , .., y_n)$ are two vectors, the Manhattan distance MD(x,y) between points X, Y can be calculated using following equation.

$$MD(x,y) = \sum_{i=1}^{n} |x_i - \ y_i|$$

2.1.6 Chebychev distance

Chebychey distance, also known as chessboard distance, is used to represent the distance between two vector points as the greatest distance difference between them. The distance between two data points "p" and "q" can be calculated using the following equation.

$$D(p,q) = \max(p_i - \ q_i)$$

2.1.7 Euclidian distance

Euclidian distance is a distance based algorithm which calculates the distance between two data points in Euclidian space [36]. Euclidian distance between two data points X and Y is the shortest length of the line connecting the two points X and Y.

Assume X and Y are two points in Cartesian space and point X is located in $X = (x_1, x_2, \dots, x_n)$ while point Y is located in $Y = (y_1, y_2, \dots, y_n)$. The distance between two points X, Y $d(x, y)$ can be derived from the equation;

$$d(x,y) = d(y,x) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \dots + (x_n - y_n)^2}$$

Or more simplified version of the equation;

$$d(x,y) = d(y,x) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

In three dimensional space the distance between X, Y points is an arrow drawn from X to Y, representing the direction vector. This can be denoted as “position of Y relative to X”. Euclidian distance $d(x, y)$ in three dimensional space can be calculated by equation;

$$d(x,y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2}$$

The Euclidian distance can be squared to place a large weight on the data items that are far apart from each other [36]. In that case the equation for calculating the distance becomes;

$$d^2(x,y) = (x_1 - y_1)^2 + (x_2 - y_2)^2 + .. + (x_n - y_n)^2$$

Because of allowing to calculate distance between two vector points in three dimensional space, Euclidian distance metric is used in “mark-less furniture layout” application in order to determine the nearest colors in an images captured during operation of suggestion feature.

Clustering of data is an important process in suggestion algorithms to achieve the best results in data classification. Although there are range of algorithms that provide clustering features, hierarchical clustering algorithm and K-Means clustering algorithm are the popular algorithms in modern data classification applications.

2.1.8 Hierarchical Clustering algorithm

Hierarchical clustering algorithm builds a hierarchy of clusters during the clustering of data which is generally fall into “agglomerative” or “divisive” clustering approaches. Agglomerative approach is a “bottom up” approach where clusters merge into a single data observation as moves up along the hierarchy. Divisive approach is a “top down” approach where clusters split as moves down along the hierarchy. Figure 2.1.5 is a representation of hierarchical clustering algorithm where each cluster is denoted in a hierarchical tree structure.

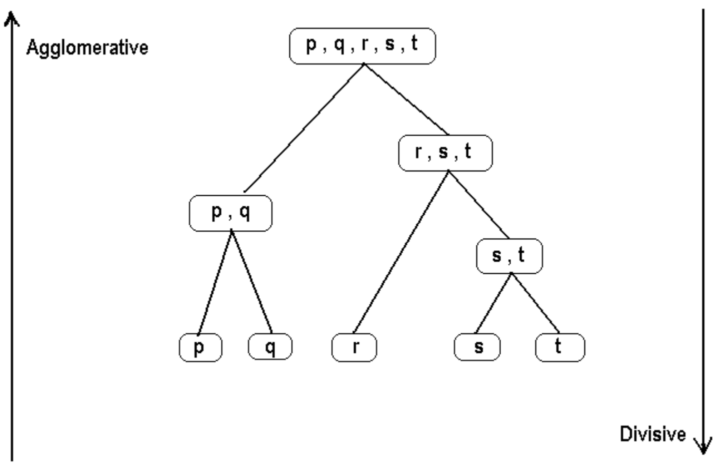


Figure 2.1.5: Hierarchical clustering algorithm

Source: http://www.solver.com/xlminer/help/hierarchical-clustering-intro

2.1.9 K-Means algorithm

K-Means algorithm is a distance based algorithm often used in unsupervised clustering of data. A distance based technique should be implemented in order to obtain the clustered results using the K-Means algorithm. The “Mark-less furniture layout” application uses above mentioned Euclidian distance metric as the technique to find the nearest colors. The K-Means algorithm consist of three main steps;

1. Initialize centroids.
2. Divide all data points through K clusters.
3. Update centroids based on new data points.

K-means algorithm takes K-value and set of data points $X_1 ... X_n$ as the inputs during initial stage. Then uses Random partition [37] method in order to initialize centroids $C_1 .. C_k$ at random locations in three dimensional vector space where the number of centroids equals to the provided K-value. Then all the data points distributed among the K number of centroids randomly.

During final step, algorithm finds the nearest data point to each centroid and assign closest data points to the nearest centroid and calculate the new mean position of the cluster centroid. The above procedure repeats until there is no any change of clusters for the given data points. The figure 2.1.6 (b) shows the final result of K-Means color clustering when provided with original image (a) with a K-value of eight.

(a) (b)

Figure 2.1.6: K- mean clustering results

When comparing with other existing clustering algorithms, K-means algorithm has number of advantages that can be utilized to overcome the problem of similar color identification in Mark-less furniture application. Some of the advantages of K-means algorithm can be listed down as follows.

- K-means algorithm is simpler and less expensive (efficient) than other popular existing algorithms in clustering data.
- Easy to implement and understand.
- K – Means clustering is computationally faster than hierarchical clustering when K value is small [38] and the data set is large.

Because of the above mentioned advantages of K-means algorithm over hierarchical clustering algorithm, Mark-less furniture application use K-means algorithm in order to classify the environmental colors captured by the device.

2.1.10 Customized approach to cluster colors

We have designed a custom method to cluster image colors. The performance of this approach will be compared with K-means algorithm in upcoming chapters. Initially all the pixel values of an image is added to a " Data Dictionary" data structure as key-value pairs of color and their pixel count. Then a modulus value is generated from each color values after converting them to HSI color model from its original RGB color model. Each modulus value is compared with other generated modulus values for equality. If the difference of two modulus values is less than 0.01, they are considered as similar colors. The figure 2.1.7 shows the flow of method execution related to this algorithm.

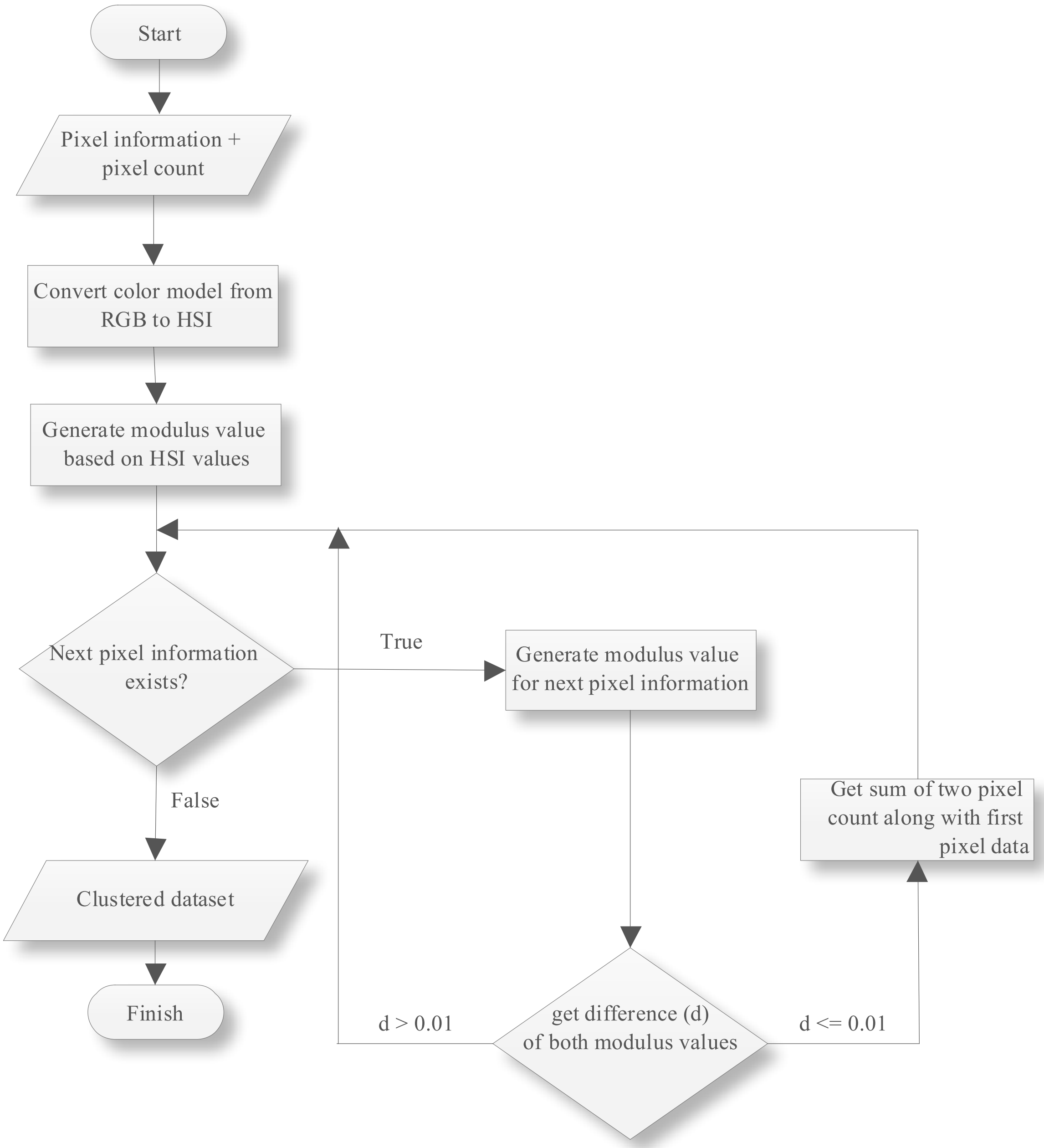


Figure 2.1.7: Custom clustering algorithm flowchart diagram

The captured image should be preprocessed to enhance its details before analyzing the pictorial details as a low contrast image may affect the color extraction algorithm negatively. Contrast can be described as the difference between maximum and minimum intensities of pixels in an image and causes due to poor illumination during image acquisition, low dynamic range in sensor or due to wrong setting in lens aperture during acquisition process. During following sections we'll describe how to identify low contrast images, existing image processing techniques that can be used to fix contrast issues and comparison between them.

2.1.11 Procedure to identify low light images

An image is consist of a collection of pixels that represent a particular color. In order to identify the intensity or the brightness of the image, image should be converted to HSI color model from the RGB color model as the "I" (intensity) component in HSI color model represent the intensity value of a single pixel. Then calculate the average intensity of each pixel's intensity level by dividing total number of intensities with number of pixels available in the image. As the above mentioned process need to monitor each pixel individually, the performance of the system degrades. In order to overcome this issue the image size is initially scaled down without affecting the prominent colors exist in the image. Figure 2.1.8 shows the flow of actions performing during the process of identifying and enhancing contrast in images.

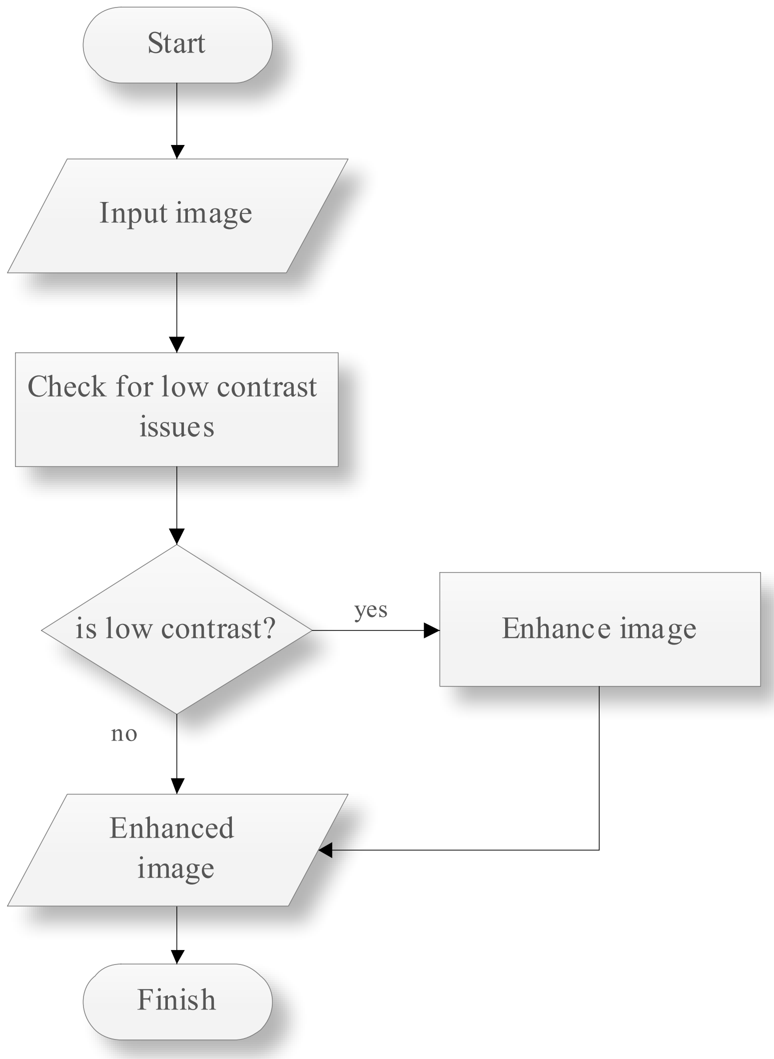


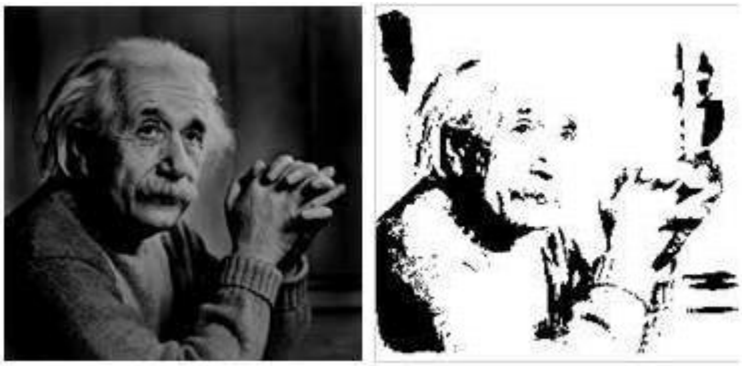
Figure 2.1.8 Color contrast detection flowchart diagram

2.1.12 Log Transformation

Log transformation is a technique used to fix contrast issues in images by adjusting the pixel intensities in the image. During the enhancement process dark pixel values in image gets expanded while light pixels values gets compressed using the equation;

$$S = c\log(1 + r)$$

Where "r" and "S" are input pixel intensity and output pixel intensity respectively. The value "c" is a constant of 106.86. Figure 2.1.9 (b) shows the resultant image when log transformation technique applied to original (a) image.



(a) (b)

Figure 2.1.9: Log transformation results

Source: http://www.tutorialspoint.com/dip/gray_level_transformations.htm

2.1.13 Contrast Stretching

Contrast stretching is a technique used to improve the contrast of an image by stretching the intensity range of the image. This technique is commonly used to enhance low contrast images.

2.1.14 Histogram Equalization

Histogram equalization is a contrast enhancement technique which use image histogram in order to adjust the contrast. This technique is commonly used for images that consist with closely related pixel values to be processed. Histogram equalization spreads most frequent pixel values while compress least frequent pixel values allowing the technique to be used to enhance both over and under exposed images. Histogram equalization process of an image involves two steps.

The histogram equalization process for an image that consist of M*N pixels and n_j occurrences of each pixel with intensity value of "j" with L number of grey levels can be demonstrated as follows.

Step 1: Construct the transformation function S_k , where "k" is a value between 0 and L-1.

$$S_k = \sum_{j=0}^{k} \frac{n_j}{M * N}$$

Step 2: Calculate the new intensity value of the pixel.

$$S_k = \frac{(L-1)}{M*N}\sum_{j=0}^{k} n_j$$

However, this method is defined for enhancing greyscale images, the technique can be applied to RGB color images by applying histogram function to each red, green and blue channels separately. Mark-less furniture application uses histogram processing technique in order to enhance images with contrast issues before continuing with the color identification algorithms, because histogram processing technique can be used for both over and under exposed images while achieving maximum computational efficiency. Figure 2.1.10 (a) and (b) shows original image and its histogram respectively. Figure 2.1.10 (c) and (d) shows histogram equalized image and its histogram respectively.

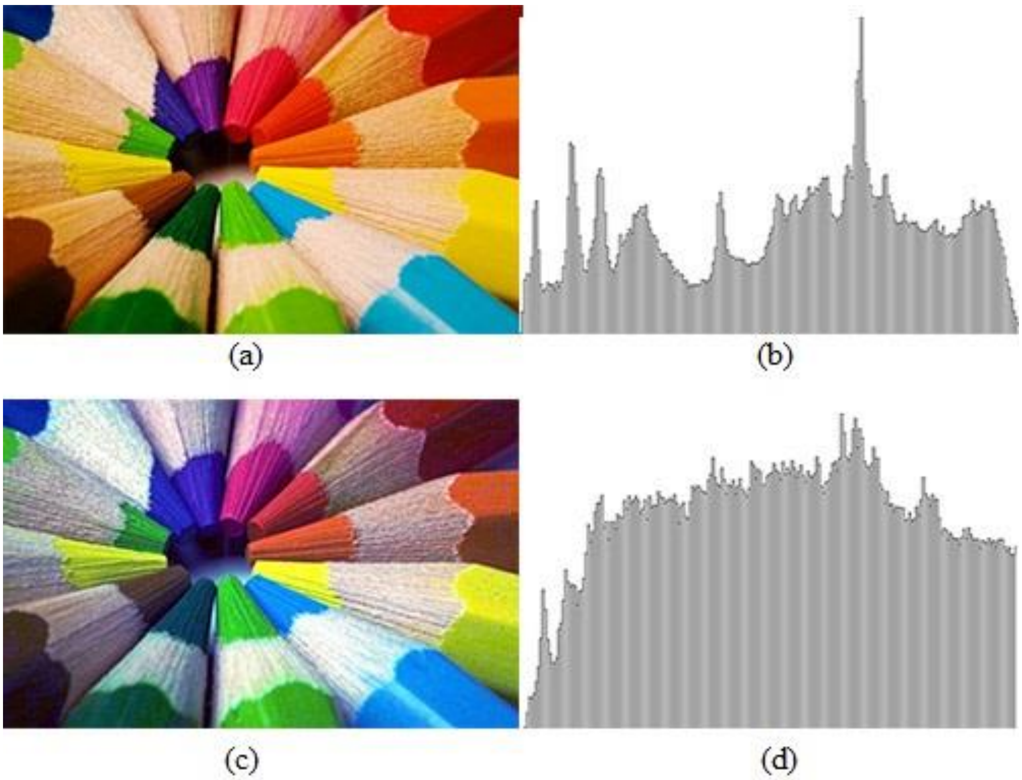


Figure 2.1.10 Histogram equitized image

Considering the above mentioned facts and the overall suggestion feature, a justification on selecting the suitable technologies and approaches can be summarized as follows.

Table 2.1.1 Summarized justification of selected technologies

Task	Available technologies/ approaches	Selected technology/ approach	Justification
Service access point for mobile application.	Web services, Web API	ASP.NET web API	• Increased efficiency. • Wider range of clients. • Easy in automation. • Efficient integration.
Message transport format.	XML , JSON	JSON	• Much simpler than the XML. • Smaller than the XML. • Serialization and deserialization is faster. • Uses less system resources.
Color representation.	RGB, CMYK, HSI	HSI	• Better capability in representing human color perception.
Find matching furniture in suggestion algorithm.	Chebychev distance, Manhattan distance, Euclidean distance	Euclidean distance	• Allow calculating distance between two vector points in three dimensional space.
Cluster image color data.	K-Means	K-Means	• Simpler and less expensive

			• Easy to implement and understand • Computationally faster than hierarchical clustering
Enhance images.	Log transformation, Contrast stretching, Histogram equalization	Histogram equalization	• Can be used for enhancing both over and under exposed images.

2.2 Testing and implementation

Mark-less furniture application uses diversified range of tools and technologies to achieve the maximum performance while providing user with the improved scalability and usability of the application. During the following sections we will be discussing about the tools, technologies and procedures used in implementations and testing of the Mark-less furniture application.

2.2.1 Implementation

The mark-less furniture application is consist of four main components as shown in table 2.2.1.

Table 2.2.1 System components

Component	Component Name	Sub Components
1.	Furniture suggestions.	i. Suggestion feature for mobile application with filter search. ii. Enhance image details. iii. Identify prominent colors. iv. Generate suggestions. v. Development of Web API to access services. vi. Develop database manager application to efficiently insert data records during development.
2.	Augmented reality furniture placement.	i. Implement augmented reality features. ii. Furniture customization. iii. Multiple furniture handling.
3.	Voice recognition.	i. Text to voice feature. ii. Customize furniture according to voice commands.
4.	Scale identification.	i. Identify real world scale to determine the actual scale of furniture.

The system uses a cloud hosted web API in order to facilitate the mobile application with implemented services and data access protocols through active network (internet) connection. The API internally connects to a hosted SQL database to retrieve and manipulate persistence data. Figure 2.2.1 (high-level system diagram) shows the overall interconnection between internal components with system interfaces and hardware interfaces which are connecting through the communication interface.

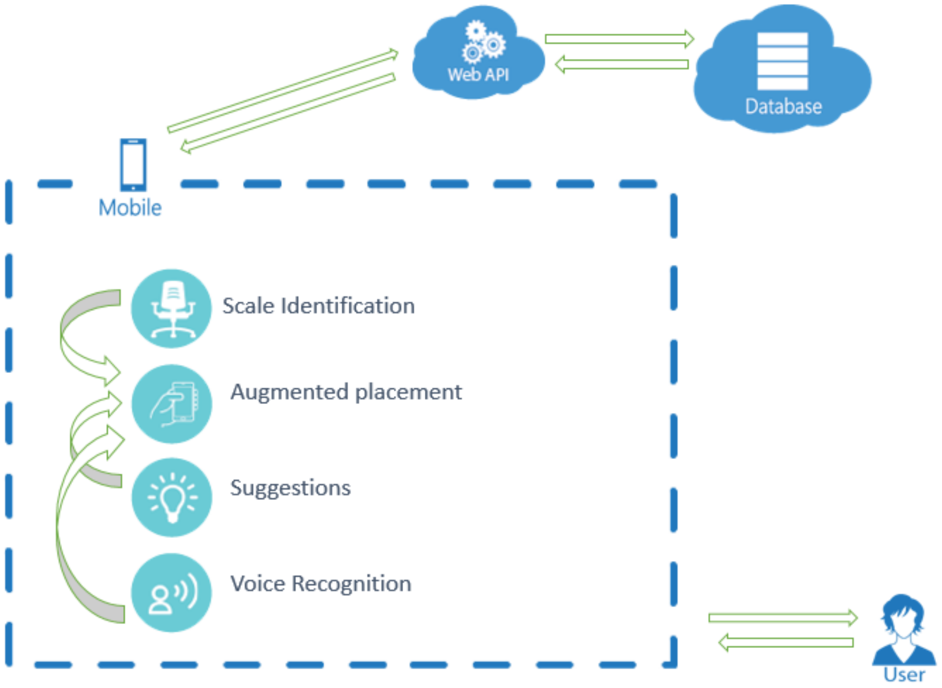


Figure 2.2.1 System diagram of the application

System interface

The Mark-less furniture application uses “FurnAR” web API developed by the development group in order to access the shared database for furniture suggestion processes and it contains the programming logic of the suggestion feature. This “FurnAR” API can be extended further to interact with any system in future development processes. The API is accessible through web link http://furnarapi.azurewebsites.net/.

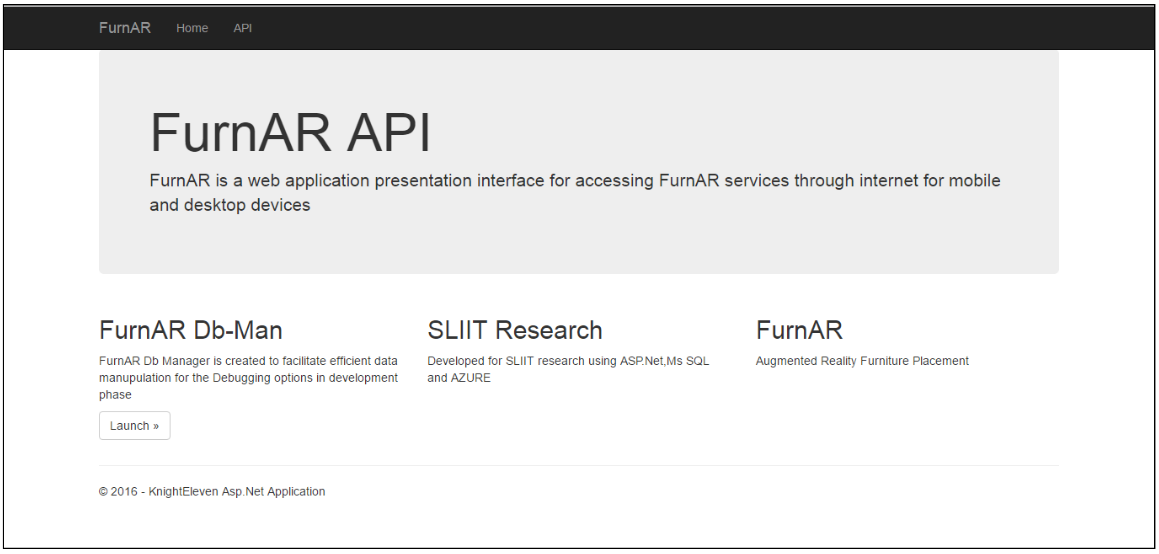


Figure 2.2.2: Developed web API

Hardware interfaces

Mobile device with android operating system (android version 4.3) is used as the main deployment environment for the Mark-less furniture system. The mobile device should consist of following hardware specifications in order to gain the maximum benefit of the application.

- Accelerometer
- Magnetometer
- Gyroscope

Communication interfaces

Since the API is hosted in a web server, active internet connection in mobile device is required for data communications with the server. A minimum bandwidth of H+ (HSDPA) is required to operate the application efficiently through the HTTP communication protocol.

Tools and technologies used in development process

The Mark-less furniture application uses latest technologies in development process. A web API application is used to provide the services requested by mobile application, which is hosted on Azure cloud hosted service. The cloud hosted Microsoft SQL database is accessed using Entity Framework allowing higher performance in data manipulation processes. Open CV sharp framework is used for basic image manipulation and data extraction processes while latest version of visual studio (visual studio 2015) and Unity IDE (version 5.3) used as the development environment which facilitate new technologies to integrate with the system. Amazon web services were used to store the 3D models of furniture designed during the implementation process.

The technologies used in development can be summarized as follows.

- ASP.NET web API
- Microsoft SQL server 2015
- Amazon Web Services (AWS) - Cloud Computing Services
- Microsoft Azure: Cloud Computing Platform & Services
- Entity Framework
- Open CV Sharp
- Visual Studio 2015
- Unity Game Development Engine 5.3
- Resharper 10.0 – to check coding standards
- PostMan Rest Client – to test web API

Coding standards

During development process, Mark-less furniture followed certain coding standards in order to achieve higher maintainability of the code. This section describes the standards followed during the development process.

Naming conventions followed.

- Use Pascal case for class names and method names.
- Use camel case for local variables and method arguments.
- Use meaningful variable names and avoid abbreviations.
- Use meaningful nouns to name classes.

Layout conventions followed.

- Indent lines properly.
- Align curly brackets vertically.
- Declare all member variables at top of the class.
- Use only one declaration per line.
- Use try-catch block for exception handling.

Finally the project was tested by coding standard inspecting software – Resharper v10 in order to remove remaining coding conflicts in the program. Figure 2.2.3 shows some of coding issues inspected by Resharper tool.

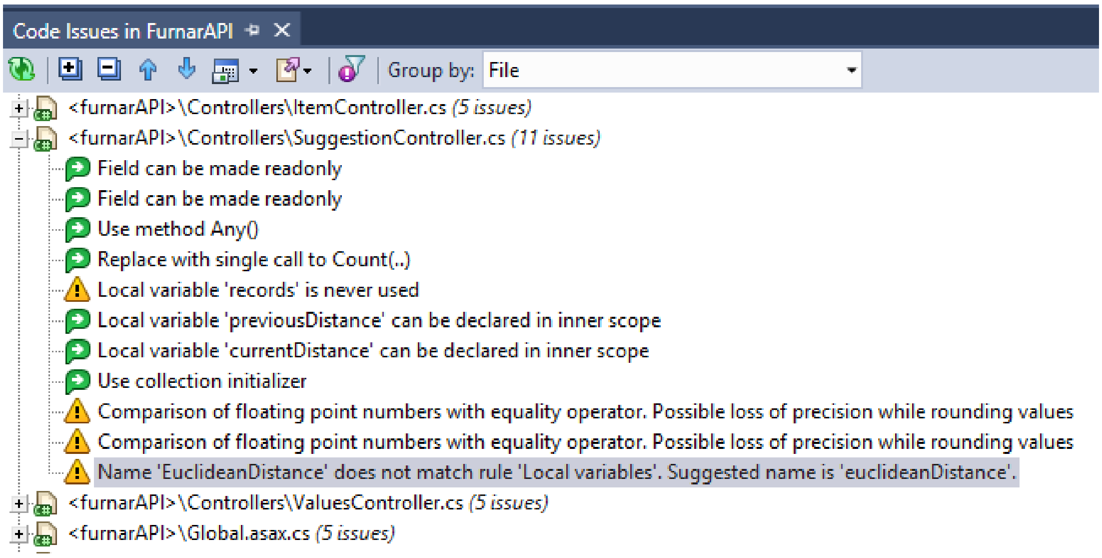


Figure 2.2.3: Inspect coding issues using ReSharper tool

Suggestion Feature

The main functionality of the suggestion feature is to provide user with efficient furniture suggestions by analyzing the environment of the user. Initially the user should capture an image of their surrounding and upload it to the web API. Internally the mobile application scale down the captured image and convert it into Base64 string format in order to transfer it through network media. On receiving the image data at web API, the API start to decode the Base64 string and recreates the captured image on server side. Afterwards the recreated image is analyzed for contrast issues where if issue exists the image is enhanced using histogram equalization technique. During next step, each and every pixel in the image gets analyzed and clustered using K-Means algorithm according to their color values. Then the image processing algorithm selects the prominent colors from the color cluster identified earlier which will be feed as an input to the furniture suggestion algorithm. Furniture suggestion algorithm uses Euclidean distance metric to match the relevant furniture with the identified prominent colors. Identified furniture details are converted into JSON messaging format and transferred back to the mobile application where the mobile application decodes the message and represent the suggested furniture models back to the user. Figure 2.2.4 shows the activity diagram of the furniture suggestion feature.

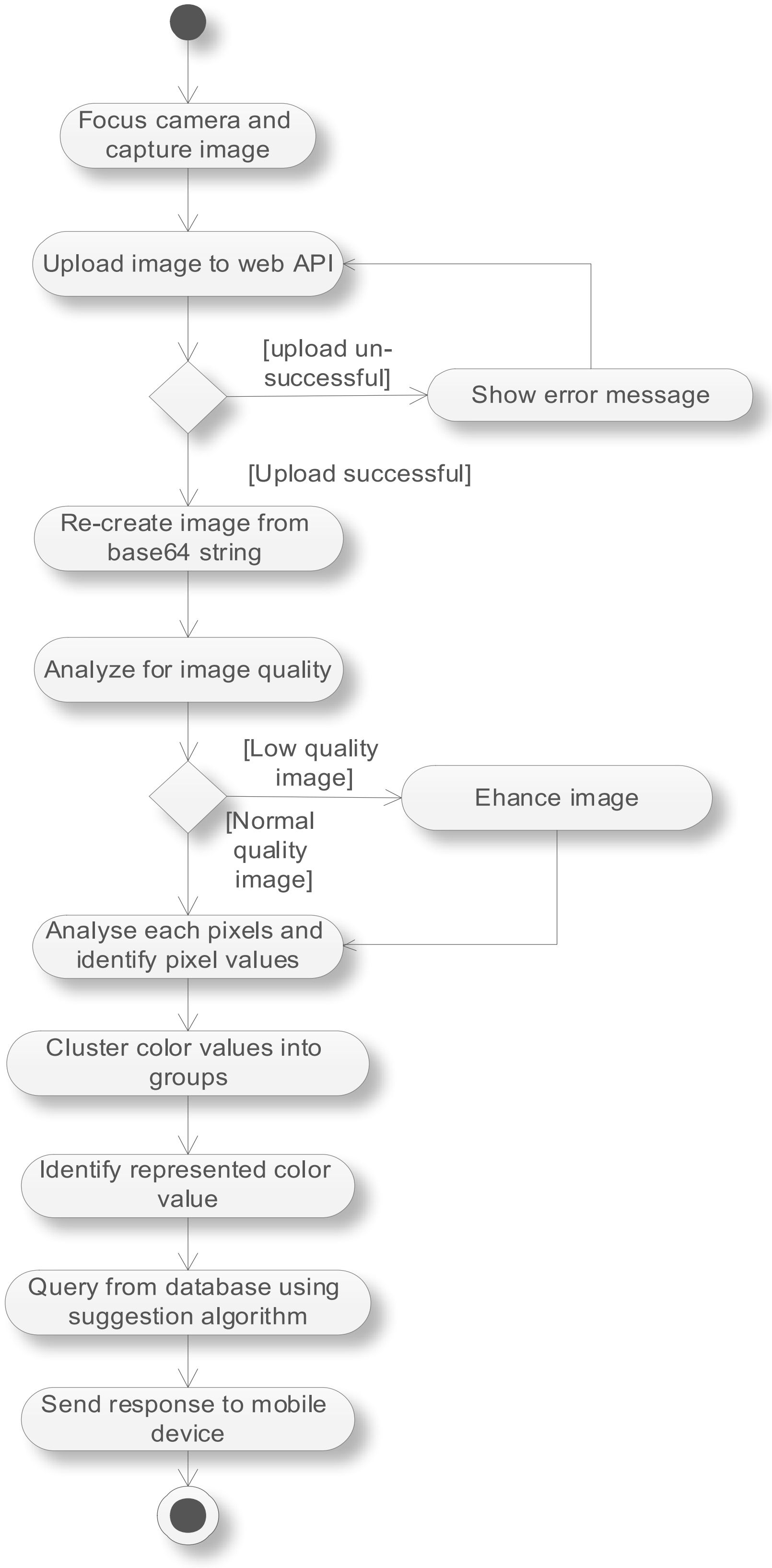


Figure 2.2.4: Activity diagram of furniture suggestion feature

2.2.2 Testing

The Mark-less furniture application is unit tested during the process of development in order to ensure that each unit create it's intended output and tested during the integration of each module to ensure that no new error caused during the integration. Finally the full system is tested against its specifications to ensure that the final product is error free and usable by an end user. User acceptance testing was conducted by two users in the furniture industry. Since performance is a major issue in networked application, the Mark-less furniture application is tested thoroughly for performance issues.

Performance Requirement

i. The mobile application should possess a captured image and generate suitable furniture suggestions within 30 seconds when captured under normal light conditions.
ii. Each web API function should complete execution within 15 seconds.
iii. The mobile application should process a captured image and generate suitable furniture suggestions within 45 seconds when captured under low and high light conditions.

Assumptions

i. Network Connection
The network should possess download bandwidth at least of 7.2Mbits/seconds and upload bandwidth at least of 3.6Mbits/second for normal performance.
ii. Memory
The mobile device memory should above 512 MB to run the application on normal conditions.
iii. Version of Operating System
The mobile device operating system should be of android operating system, version above 4.3 (Jelly Bean).

Testing Methodology

The web API URL's are tested for response code 200-0k using Postman Rest client and the time taken for the response is marked under two different network bandwidths. Each public method in the web API is tested for three different images each 5 times. The private methods in the web API will not be covered in this testing as they are already covered during public method evaluations.

Images used in testing

i. Image_1 - Low light image (Dimension 512x300 pixels)

Figure 2.2.5 Low light image (under exposed)

ii. Image_2 - Normal light image (Dimension 512x300 pixels)

Figure 2.2.6 Normal light image (normal)

iii. Image_3 - High light image (Dimension 512x300 pixels)

Figure 2.2.7 High light image (over exposed)

The final test outcomes and the conclusion will be explained in chapter three (Results and discussions).

2.3 Research findings

The objective of Mark-less furniture application was to develop an application that increase the customer satisfaction during the process of purchasing furniture while providing marketing benefits to the furniture dealers. Research was performed using several existing technologies and by considering the efficiency and benefits of the used technologies, the technologies that should include in the Mark-less furniture application is selected. The HSI color model was selected over existing RGB and CMYK color models as it is more close to human color perception and K-means algorithm was selected over Hierarchical algorithm, because it is much simpler and efficient when having large amounts of data to be clustered. Mark-less furniture application was produced as the final outcome by considering all the facts explained in section 2.1 (Methodology approach) in order to overcome the problems explained in section 1.3 (Research problem) using the approach explained in section 2.2.1 (implementation).

3 RESULTS AND DISCUSSIONS

A performance test is conducted under the network connectivity of both WIFI network bandwidth (802.11 standard) and under mobile network bandwidth HSPA (H) while following the constraints and guidelines explained in section 2.2 (Testing). The conducted test yield following results for each method exposed in web API under mobile network bandwidth connectivity speed of HSPA and WIFI connectivity.

3.1 Results

3.1.1 Results for test conducted under mobile network bandwidth HSPA.

The conducted test satisfy the following specifications of the network.

- Ping: 23ms
- Download speed: 3.54 Mbps
- Upload speed: 1.95 Mbps

Test results for SuggestionController. GetSuggestionsFromColorName () function

Table 3.1.1 Test results for GetSuggestionFromColorName

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	20032	200
2	Image_1	Low light image	6698	200
3	Image_1	Low light image	4974	200
4	Image_1	Low light image	6039	200
5	Image_1	Low light image	4940	200
6	Image_2	Balanced light image	9092	200
7	Image_2	Balanced light image	9386	200
8	Image_2	Balanced light image	8597	200
9	Image_2	Balanced light image	8763	200
10	Image_2	Balanced light image	9503	200

11	Image_3	High light image	12793	200
12	Image_3	High light image	12345	200
13	Image_3	High light image	11011	200
14	Image_3	High light image	11930	200
15	Image_3	High light image	13915	200

Test results for SuggestionController. GetSuggestionsForNearestColor () function

Table 3.1.2 Test results for GetSuggestionsForNearestColor

Id	**Image**	**Image description**	**Execution time(ms)**	**Response status**
1	Image_1	Low light image	6160	200
2	Image_1	Low light image	4937	200
3	Image_1	Low light image	4076	200
4	Image_1	Low light image	4109	200
5	Image_1	Low light image	4080	200
6	Image_2	Balanced light image	7743	200
7	Image_2	Balanced light image	4421	200
8	Image_2	Balanced light image	4432	200
9	Image_2	Balanced light image	4831	200
10	Image_2	Balanced light image	3601	200
11	Image_3	High light image	6149	200
12	Image_3	High light image	5028	200
13	Image_3	High light image	5010	200
14	Image_3	High light image	6838	200
15	Image_3	High light image	5043	200

Test results for ImageProcessController. GetMeanedColorNames () function

Table 3.1.3 Test results for GetMeanedColorNames

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	2812	200
2	Image_1	Low light image	454	200
3	Image_1	Low light image	506	200
4	Image_1	Low light image	462	200
5	Image_1	Low light image	436	200
6	Image_2	Balanced light image	1412	200
7	Image_2	Balanced light image	491	200
8	Image_2	Balanced light image	552	200
9	Image_2	Balanced light image	540	200
10	Image_2	Balanced light image	548	200
11	Image_3	High light image	2882	200
12	Image_3	High light image	1537	200
13	Image_3	High light image	1440	200
14	Image_3	High light image	1507	200
15	Image_3	High light image	1417	200

Test results for ImageProcessController. GetNonMeanedColorNames () function

Table 3.1.4 Test results for GetNonMeanedColorNames

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	1967	200
2	Image_1	Low light image	1113	200
3	Image_1	Low light image	1101	200
4	Image_1	Low light image	1948	200
5	Image_1	Low light image	1118	200
6	Image_2	Balanced light image	6473	200

7	Image_2	Balanced light image	4554	200
8	Image_2	Balanced light image	4590	200
9	Image_2	Balanced light image	4528	200
10	Image_2	Balanced light image	5621	200
11	Image_3	High light image	9401	200
12	Image_3	High light image	7889	200
13	Image_3	High light image	7254	200
14	Image_3	High light image	8022	200
15	Image_3	High light image	6986	200

Test results for ImageProcessController. GetMeanedColorValues () function

Table 3.1.5 Test results for GetMeanedColorValues

Id	**Image**	**Image description**	**Execution time(ms)**	**Response status**
1	Image_1	Low light image	1102	200
2	Image_1	Low light image	256	200
3	Image_1	Low light image	443	200
4	Image_1	Low light image	470	200
5	Image_1	Low light image	479	200
6	Image_2	Balanced light image	5162	200
7	Image_2	Balanced light image	1502	200
8	Image_2	Balanced light image	1370	200
9	Image_2	Balanced light image	484	200
10	Image_2	Balanced light image	491	200
11	Image_3	High light image	1498	200
12	Image_3	High light image	553	200
13	Image_3	High light image	697	200
14	Image_3	High light image	1719	200
15	Image_3	High light image	525	200

Test results for ImageProcessController. GetNonMeanedColorValues () function

Table 3.1.6 Test results for GetNonMeanedColorValues

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	5585	200
2	Image_1	Low light image	4889	200
3	Image_1	Low light image	2360	200
4	Image_1	Low light image	2143	200
5	Image_1	Low light image	1283	200
6	Image_2	Balanced light image	8051	200
7	Image_2	Balanced light image	5459	200
8	Image_2	Balanced light image	4804	200
9	Image_2	Balanced light image	4753	200
10	Image_2	Balanced light image	5585	200
11	Image_3	High light image	9812	200
12	Image_3	High light image	6966	200
13	Image_3	High light image	6969	200
14	Image_3	High light image	6982	200
15	Image_3	High light image	7957	200

3.1.2 Results for test conducted under WIFI network bandwidth (802.11 standard).

The conducted test satisfy the following specifications of the network.

- Ping: 23ms
- Download speed: 3.54 Mbps
- Upload speed: 1.95 Mbps

Test results for SuggestionController. GetSuggestionsFromColorName () function

Table 3.1-7 Test results for GetSuggestionFromColorName

Id	Image	Image description	Execution time(ms)	HTTP Response status
1	Image_1	Low light image	18608	200
2	Image_1	Low light image	4781	200
3	Image_1	Low light image	4783	200
4	Image_1	Low light image	4785	200
5	Image_1	Low light image	4812	200
6	Image_2	Balanced light image	9139	200
7	Image_2	Balanced light image	9059	200
8	Image_2	Balanced light image	9500	200
9	Image_2	Balanced light image	8903	200
10	Image_2	Balanced light image	8933	200
11	Image_3	High light image	15163	200
12	Image_3	High light image	11621	200
13	Image_3	High light image	11490	200
14	Image_3	High light image	11705	200
15	Image_3	High light image	11587	200

Test results for SuggestionController. GetSuggestionsForNearestColor () function

Table 3.1-8 Test results for GetSuggestionsForNearestColor

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	4343	200
2	Image_1	Low light image	4367	200
3	Image_1	Low light image	4397	200
4	Image_1	Low light image	4361	200
5	Image_1	Low light image	4400	200

6	Image_2	Balanced light image	5078	200
7	Image_2	Balanced light image	3800	200
8	Image_2	Balanced light image	3805	200
9	Image_2	Balanced light image	3765	200
10	Image_2	Balanced light image	5049	200
11	Image_3	High light image	5284	200
12	Image_3	High light image	5327	200
13	Image_3	High light image	5106	200
14	Image_3	High light image	5234	200
15	Image_3	High light image	5253	200

Test results for ImageProcessController. GetMeanedColorNames () function

Table 3.1-9 Test results for GetMeanedColorNames

Id	**Image**	**Image description**	**Execution time(ms)**	**Response status**
1	Image_1	Low light image	555	200
2	Image_1	Low light image	518	200
3	Image_1	Low light image	453	200
4	Image_1	Low light image	442	200
5	Image_1	Low light image	506	200
6	Image_2	Balanced light image	554	200
7	Image_2	Balanced light image	586	200
8	Image_2	Balanced light image	553	200
9	Image_2	Balanced light image	613	200
10	Image_2	Balanced light image	594	200
11	Image_3	High light image	639	200
12	Image_3	High light image	658	200
13	Image_3	High light image	603	200
14	Image_3	High light image	594	200
15	Image_3	High light image	641	200

Test results for ImageProcessController. GetNonMeanedColorNames () function

Table 3.1-10 Test results for GetNonMeanedColorNames

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	1418	200
2	Image_1	Low light image	1245	200
3	Image_1	Low light image	1546	200
4	Image_1	Low light image	1342	200
5	Image_1	Low light image	1278	200
6	Image_2	Balanced light image	5162	200
7	Image_2	Balanced light image	5146	200
8	Image_2	Balanced light image	5167	200
9	Image_2	Balanced light image	5191	200
10	Image_2	Balanced light image	5079	200
11	Image_3	High light image	7704	200
12	Image_3	High light image	7712	200
13	Image_3	High light image	7707	200
14	Image_3	High light image	7706	200
15	Image_3	High light image	7705	200

Test results for ImageProcessController. GetMeanedColorValues () function

Table 3.1-11 Test results for GetMeanedColorValues

Id	Image	Image description	Execution time(ms)	Response status
1	Image_1	Low light image	551	200
2	Image_1	Low light image	463	200
3	Image_1	Low light image	489	200
4	Image_1	Low light image	498	200
5	Image_1	Low light image	457	200
6	Image_2	Balanced light image	589	200

7	Image_2	Balanced light image	582	200
8	Image_2	Balanced light image	547	200
9	Image_2	Balanced light image	569	200
10	Image_2	Balanced light image	543	200
11	Image_3	High light image	637	200
12	Image_3	High light image	629	200
13	Image_3	High light image	643	200
14	Image_3	High light image	618	200
15	Image_3	High light image	623	200

Test results for ImageProcessController. GetNonMeanedColorValues () function

Table 3.1-12 Test results for GetNonMeanedColorValues

Id	**Image**	**Image description**	**Execution time(ms)**	**Response status**
1	Image_1	Low light image	1152	200
2	Image_1	Low light image	1141	200
3	Image_1	Low light image	1234	200
4	Image_1	Low light image	1178	200
5	Image_1	Low light image	1123	200
6	Image_2	Balanced light image	4914	200
7	Image_2	Balanced light image	4943	200
8	Image_2	Balanced light image	4879	200
9	Image_2	Balanced light image	4967	200
10	Image_2	Balanced light image	4897	200
11	Image_3	High light image	7607	200
12	Image_3	High light image	7654	200
13	Image_3	High light image	7456	200
14	Image_3	High light image	7312	200
15	Image_3	High light image	7566	200

3.2 Discussion

By analyzing the above performance data, it is clear that the initial image processing request sent to the web API takes longer time than the consecutive requests for each new image. This means that the server response time for initial request is higher than the requests following it. This slow response occurs because the hosted web API only loads its details on first incoming request. If no any incoming request arrives at server within a fixed amount of time, the server automatically stops again. This can be overcome by keeping the server always running but as a result of that the cost for the resources gets increases.

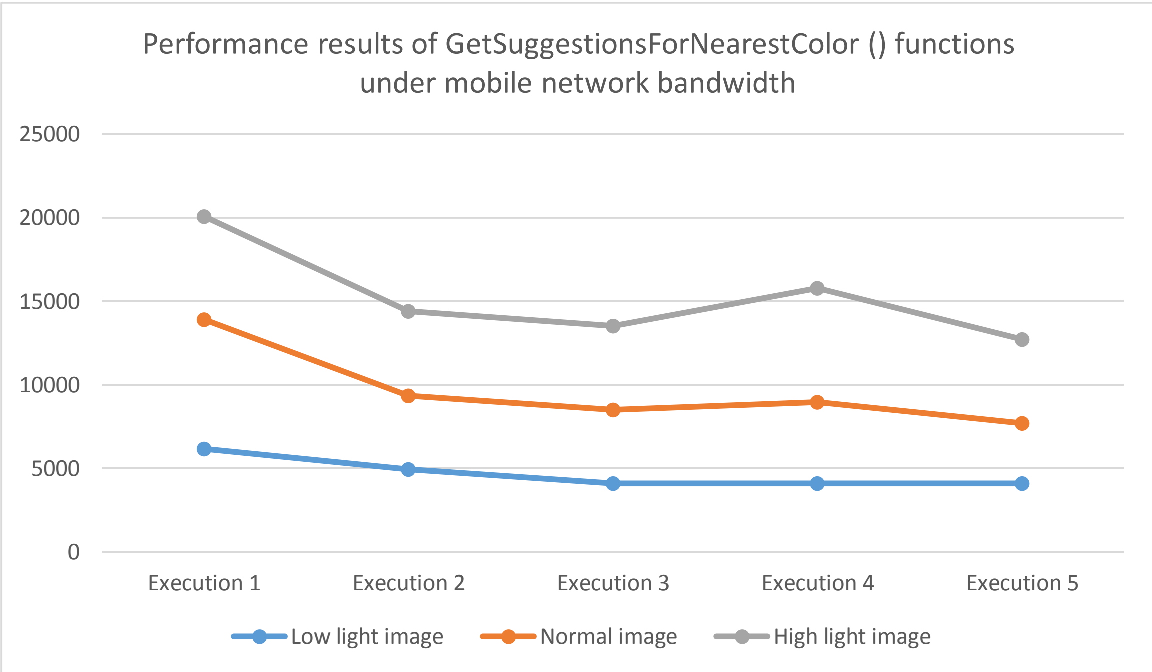


Figure 3.2.1 Performance result comparison of suggestion algorithm

From the test information gathered during the testing process, it is clear that the time to process an image which is over exposed to light is higher than the time it takes to process a regular image and time taken to process a regular image is higher than the time taken to process a under exposed image. This occurs since an image with more white pixels have larger storage size and thus need higher computational power and resources in order to process the image than other images. The processing time can be further decreased by reducing the scale of the image. But still the processing time required to process over light exposed image is higher than that of a normal image.

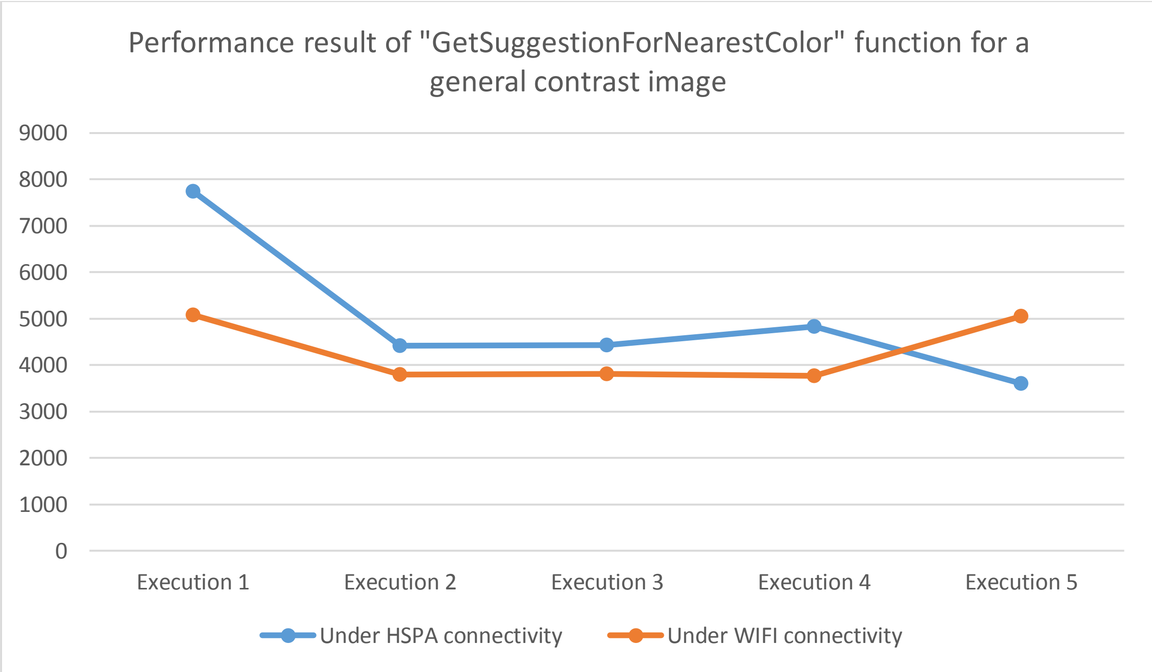


Figure 3.2.2 Test comparison of connectivity technologies

Although the initial execution times are different in test results generated under mobile HSPA connectivity, the overall performance of the execution is similar to that of WIFI connectivity. Analyzing the information in figure 3.2.2 we can arrive at a conclusion that although the connectivity technology is advanced, the execution time mainly depends on data upload speed and only server response is effected largely by the download speed of the network in use.

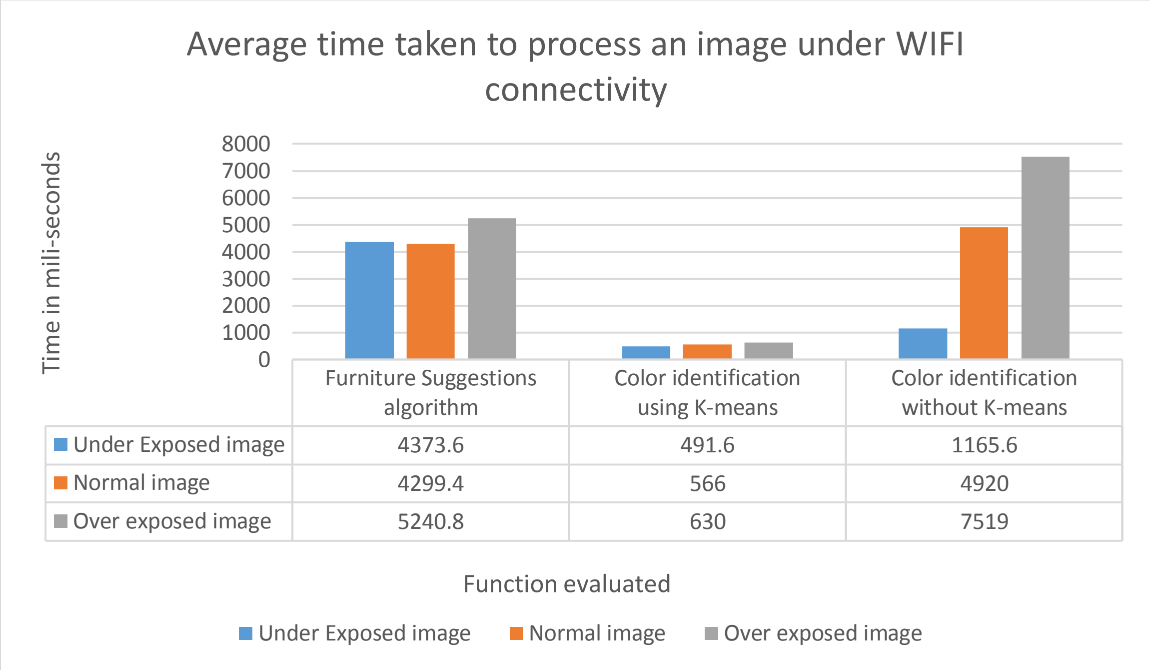


Figure 3.2.3 Average processing times under WIFI connectivity

As described in section 2.2.2 (performance requirement), the performance requirement for web API to process a request is maximum of 15 seconds. By analyzing the test results in figure 3.2.3, it is clear that the average time taken by the suggestion algorithm is less than 6 seconds which reflect the fact that the Mark-less furniture application is according to the specified performance requirement. Figure 3.2.3 also shows that by using K-means algorithm the system can achieve large performance benefit than without using it during the process of color clustering.

For each public exposed function in web API, response time is monitored to determine whether the execution time is less than ten seconds. The test is conducted over 180 input values and Figure 3.2.4 shows the analysis results of the approach. From 180 test entries 168 test cases are according to the performance criteria and 12 test entries violate the performance criteria of the web API.

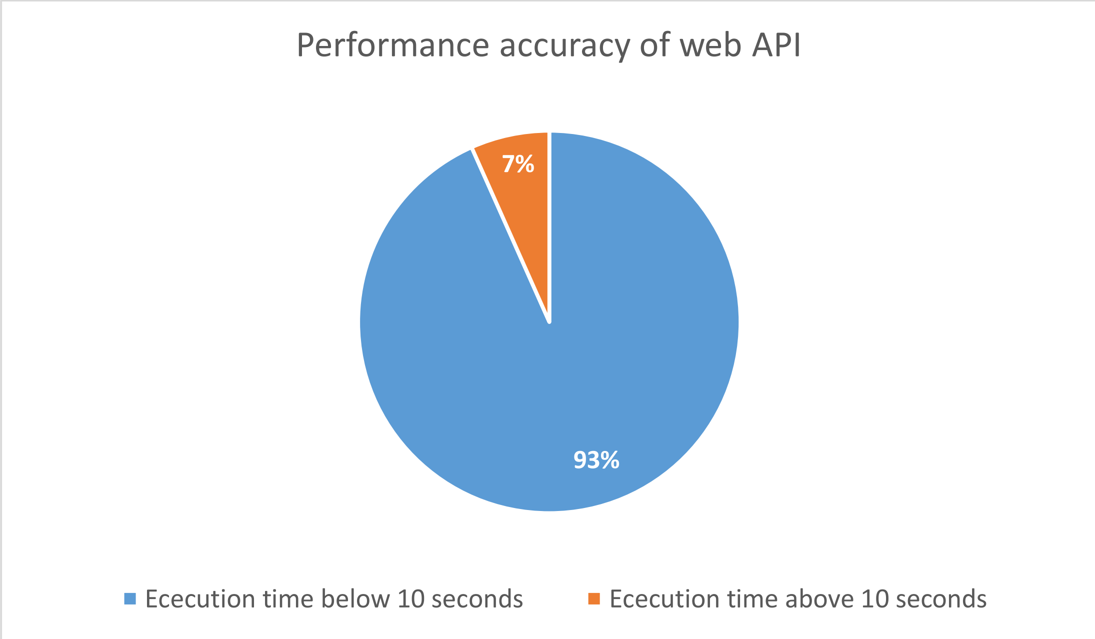


Figure 3.2.4: Performance accuracy of web API

The time taken to process the request can be further reduced by utilizing a powerful host server for the web API. Most of the enterprise web hosting servers provide more storage space and dynamic bandwidth that can be adjust according to the growing web traffic.

4 CONCLUSION

Over the past few decades, improvement of new marketing strategies reached to an advanced level in business. With invent of new smart phones goals of marketing have moved towards the mobility and reachability of the business from traditional techniques. This increase the number of customers reaching a particular business and thus the satisfaction ratio of the customer should be increased in order to earn a market value among other competitive businesses.

This research provide a modern solution to the furniture marketing industry in order to increase the customer satisfaction while surviving in the competitive business world. The identified solution mainly focused on providing augment reality or a mixed virtual experience to the users which facilitate them to interact with computer generated 3D models placed on their environment.

Considering the performance data gathered during the testing phase, it is clear that the K-Means algorithm is suitable for color clustering than the custom method developed. As a result of that Mark-less furniture continue the use of identified K-means algorithm in clustering colors. The developed approach was tested for the accuracy by analyzing images having different colors and the performance results were 93% accurate.

The research is mainly focused on studying how an efficient suggestion algorithm can be developed using image processing techniques to overcome the problems caused in furniture marketing industry. The developed solution is capable of generating real-time furniture suggestions according to the environmental colors. This algorithm can be further developed by taking measures to suggest furniture depending on purchasing patterns of the customer using data mining techniques.

REFERENCES

[1] Department of Census and Statistics, "Report on Index of Industrial Production", Ministry of National Policy and Economics Affairs, 2016.

[2] J. Ma and J. Choi, "The Virtuality and Reality of Augmented Reality", *Journal of Multimedia*, vol. 2, no. 1, 2007.

[3] E. Carvalho, G. Maçães, I. Varajão, N. Sousa and P. Brito, "Use of Augmented Reality in the furniture industry", *Proceedings of the 1st Experiment@ International Conference*.

[4] A. Comport, E. Marchand and F. Chaumette, "A real-time tracker for markerless augmented reality", *The Second IEEE and ACM International Symposium on Mixed and Augmented Reality, 2003. Proceedings.*

[5] R. Azuma, Y. Baillot, R. Behringer, S. Feiner, S. Julier and B. MacIntyre, "Recent advances in augmented reality", *IEEE Comput. Grap. Appl.*, vol. 21, no. 6, pp. 34-47, 2001.

[6] U. Neumann and A. Majoros, "Cognitive, performance, and systems issues for augmented reality applications in manufacturing and maintenance", *Proceedings. IEEE 1998 Virtual Reality Annual International Symposium (Cat. No.98CB36180)*.

[7] P. Merrell, E. Schkufza, Z. Li, M. Agrawala and V. Koltun, "Interactive furniture layout using interior design guidelines", *TOG*, vol. 30, no. 4, p. 1, 2011.

[8] "Color", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Color. [Accessed: 01- Sep- 2016].

[9] "Electromagnetic spectrum", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Electromagnetic_spectrum. [Accessed: 01- Sep- 2016].

[10] "How do we perceive color? | ColoRotate", *Learn.colorotate.org*. [Online]. Available: http://learn.colorotate.org/how-do-we-perceive-color/#.V7Z3Dfl97IW. [Accessed: 01- Sep- 2016].

[11] R. Gonzalez and R. Woods, *Digital image processing*. Upper Saddle River, N.J.: Prentice Hall, 2008.

[12] R. Brown and D. MacLeod, "Color appearance depends on the variance of surround colors", *Current Biology*, vol. 7, no. 11, pp. 844-849, 1997.

[13] S. Allred and M. Olkkonen, "The effect of background and illumination on color identification of real, 3D objects", *Frontiers in Psychology*, vol. 4, 2013.

[14] Q. Zaidi, "Identification of illuminant and object colors: heuristic-based algorithms", *Journal of the Optical Society of America A*, vol. 15, no. 7, p. 1767, 1998.

[15] "Checker shadow illusion", *Wikipedia*, 2005. [Online]. Available: https://en.wikipedia.org/wiki/Checker_shadow_illusion. [Accessed: 01- Sep- 2016].

[16] "Color psychology", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Color_psychology. [Accessed: 01- Sep- 2016].

[17] "The Placebo Effect: What Is It?", *WebMD*, 2016. [Online]. Available: http://www.webmd.com/pain-management/what-is-the-placebo-effect. [Accessed: 01- Sep- 2016].

[18] A. Hurlbert and Y. Ling, "Biological components of sex differences in color preference", *Current Biology*, vol. 17, no. 16, pp. R623-R625, 2007.

[19] K. Schloss and S. Palmer, "An ecological valence theory of human color preferences", *Journal of Vision*, vol. 9, no. 8, pp. 358-358, 2010.

[20] S. Rege, R. Memane, M. Phatak and P. Agarwal, "2D GEOMETRIC SHAPE AND COLOR RECOGNITION USING DIGITAL IMAGE PROCESSING", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 2, no. 6, 2013.

[21] S. Chhaya, S. Khera and P. Kumar, "BASIC GEOMETRIC SHAPE AND PRIMARY COLOUR DETECTION USING IMAGE PROCESSING ON MATLAB", *International Journal of Research in Engineering and Technology*, vol. 04, no. 05, pp. 505-509, 2015.

[22] A. Morin, "How To Use Color Psychology To Give Your Business An Edge", *Forbes.com*, 2014. [Online]. Available: http://www.forbes.com/sites/amymorin/2014/02/04/how-to-use-color-psychology-to-give-your-business-an-edge/#4db334df2e28. [Accessed: 01- Sep- 2016].

[23] A. Singh, A. Yadav and A. Rana, "K-means with Three different Distance Metrics", *International Journal of Computer Applications*, vol. 67, no. 10, pp. 13-17, 2013.

[24] "Home - Sayduck", *Sayduck.com*. [Online]. Available: http://sayduck.com/business/. [Accessed: 01- Sep- 2016].

[25] "Home", *Vuforia.com*. [Online]. Available: http://www.vuforia.com/. [Accessed: 01- Sep- 2016].

[26] "Augmented Furniture | Try furniture in real time, buy with confidence.", *Augmentedfurniture.com*. [Online]. Available: http://www.augmentedfurniture.com/. [Accessed: 01- Sep- 2016].

[27] "uDecore - Home Decoration with Augmented Reality", *Viutek.com*. [Online]. Available: http://www.viutek.com/udecore.html. [Accessed: 01- Sep- 2016].

[28] "Augmented reality for Interior Design - Augment", *Augment*. [Online]. Available: http://www.augment.com/augmented-reality-for-interior-design/. [Accessed: 01- Sep- 2016].

[29] "Application programming interface", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Application_programming_interface. [Accessed: 01- Sep- 2016].

[30] "XML vs JSON", *Cs.tufts.edu*. [Online]. Available: http://www.cs.tufts.edu/comp/150IDS/final_papers/tstras01.1/FinalReport/FinalReport.html#xml-advantages. [Accessed: 01- Sep- 2016].

[31] N. Nurseitov, M. Paulson, R. Reynolds, and C. Izurieta. “Comparison of JSON and XML Data Interchange Formats: A Case Study”. Unpublished.

[32] A. Sumaray and S. Makki, "A comparison of data serialization formats for optimal efficiency on a mobile platform", *Proceedings of the 6th International Conference on Ubiquitous Information Management and Communication - ICUIMC '12*, 2012.

[33] "What is CMYK (cyan, magenta, yellow, key)? - Definition from WhatIs.com", *WhatIs.com*, 2005. [Online]. Available: http://whatis.techtarget.com/definition/CMYK-cyan-magenta-yellow-key. [Accessed: 01- Sep- 2016].

[34] "HSL and HSV", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/HSL_and_HSV. [Accessed: 01- Sep- 2016].

[35] H. Cheng, X. Jiang, Y. Sun and J. Wang, "Color image segmentation: advances and prospects", *Pattern Recognition*, vol. 34, no. 12, pp. 2259-2281, 2001.

[36] "Euclidean distance", *Wikipedia*. [Online]. Available: https://en.wikipedia.org/wiki/Euclidean_distance. [Accessed: 01- Sep- 2016].

[37] G. Hamerly and C. Elkan, "Alternatives to the k-means algorithm that find better clusterings", *Proceedings of the eleventh international conference on Information and knowledge management - CIKM '02*, 2002.

[38] "K-Means Clustering Overview", *Improvedoutcomes.com*. [Online]. Available: http://www.improvedoutcomes.com/docs/WebSiteDocs/Clustering/K-Means_Clustering_Overview.htm. [Accessed: 01- Sep- 2016].