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ORIGINAL RESEARCH

A fuzzy-based expert system to analyse purchase behaviour under uncertain environment

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Abstract This study develops a Mamdani based Fuzzy inference model to explore the behaviour of customers during purchase of an E-commerce product under an uncertain environment. For the purpose of illustration, product laptop has been considered. The data for this study is primarily collected through questionnaire that involved around 464 participants who are habituated to such online purchase, thus, improving the authenticity of the study. Six such independent input variables like Brand name, Processor speed, RAM capacity, internal storage, Screen size and Graphics are considered in the study. The study proposes Mamdani based Fuzzy inference model that has six inputs and one output. Each input variable is measured on a scale expressed in linguistic terms. For the model, set of all possible rules are generated in the form of antecedent and consequences principle. The proposed model establishes a basis for understanding the influence of various input parameters on the purchase behaviour.

Keywords FLC · E-commerce · Purchase behaviour · Uncertain environment

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1 Introduction

In the era of technological revolution, Internet is accessible to individual on finger tips. This convenient access to Internet has resulted a significant transformation in the shopping habits. Moreover, it also leads to emergence of new business entities (online and offline) in market and thus leading to explosion of data [8]. Each online business entity is trying its level best to garner maximum share of business and thus, have been trying various tactics to lure customers. If these companies succeed in attracting a significant portion of the market, it will boost their professional reputation and brand image [10]. Thus, E-commerce is a key business strategy which enables companies to achieve their goals and improve their position as online purchase makes a huge share of each business.

Apart from numerous benefits, online purchase has some associated challenges as well. Shopping through e-commerce sites is quite challenging as it involves a particular product by different brands and configuration, obscuring the process of product selection for customer. For Instance, product laptop is available in wide range of varieties (For Notebook, Ultrabook, Gaming laptop, Workstations); from different brands (HP, DELL, Wipro, HCL etc.); for different group of customers. With this wide range of options,

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it becomes difficult for the customer to select a particular product which can accomplish his/her needs. It necessitates expertise to choose a particular product that satisfies users' need in a cost effective manner. This attracted the authors towards customers' behaviour analysis during purchase of such product. Efficient analysis of this behaviour aids to devise an expert recommendation system that may help customer in choosing the right product online based on its wide domain knowledge.

Recommender systems help users by suggesting the right product in accordance with customer's requirements among a wide range of products [12]. Such a recommender system considers user profile, item profile or explicit user inputs to suggest the relevant product to a particular user based on his preferences (implicit and explicit) using information filtering techniques. From past few years, there has been significant development in creating personalized systems by leading websites like Amazon, Netflix etc. [15]. These websites employ recommender system to recommend various products like movies, sports, clothing, electronic devices etc. to customers based on his interests, shopping behaviour and browsing history [13, 17].

Customers often express their interests on E-commerce sites in the form of linguistic word like "bad", "good", "very good" [2, 17]. Such linguistic terms (used by the customers to describe their preferences) are exploited by fuzzy set techniques to evaluate the satisfaction level of customers and thus, aids in designing an effective recommender system [14]. Thus, fuzzy set technique is competent to address these challenges and enables customer to choose the right product without much effort [4]. Moreover, it also aids companies to understand the purchasing behaviour of various customers so that attractive business strategies could be devised to attract customers [1, 11]. Thus, it is clear that fuzzy techniques can be employed to perceive the users' behaviour towards a particular product.

The paper primarily contributes to assist purchase of a product in an uncertain environment by devising a mathematical model for the same. The remainder of the paper is organized as follows. In Sect. 2, research background is presented about applicability of fuzzy system for decision making in an uncertain environment. Section 3 discusses the proposed Mamdani based fuzzy expert system (FES). The results of the proposed system are discussed in Sect. 4. Finally, the conclusion and future scope is presented in Sect. 5.

2 Related Work

This section presents the work by various researchers who have proposed mathematical models for decision making in an uncertain environment. It is noticed during literature survey that the Fuzzy modelling is an appropriate choice for the same.

The research work in order to understand the purchase behavior through fuzzy systems has been carried out by various researchers during the past few decades. The authors in [4] established that there are several factors that influence the customer's choice during purchase in a fuzzy environment. The study is motivated by the intention of each business entity to maximize the market share and surpass the competitors. The authors in [4] propose a Fuzzy Multiple Criteria Decision Making (FMCDM) model to apprehend customer's choice behavior.

Authors in [9] devised a mathematical model using fuzzy modelling that works in four stages viz. information collection, information compilation, information execution and finally decision making. For the same, authors in [9] employ fuzzy set theory owing to its competence to quantify linguistic expressions to mathematical form. The paper advocates employment of Intuitionistic fuzzy set (IFSs) so as to help solving real life problems in uncertain environment. The work is extended further by the author in [15] by devising a mathematical decision model for selecting a cell phone for purchase. The undertaken problem is multi-criteria decision-making (MCDM) with conflicting and diverse objectives. Here, authors suggested a Mamdani approach that has seven independent input variables and provides one output variable. Here, each input variable is measured on a Likert scale that helps to arrive at better understanding of the mobile selection.

Similar work is also carried out by researchers in [5]. Here, authors aim to aid decision making for software selection using fuzzy AHP (analytic hierarchy process) and fuzzy TOPSIS (technique for order preference by similarity to ideal solution). The proposed system firstly determines the priority values of criteria in software selection using fuzzy AHP as it takes less computation time and is simpler. Thereafter, it employs fuzzy TOPSIS model to evaluate the most appropriate choice in an uncertain environment. The results of proposed model are compared with traditional systems and it is observed that proposed methodology minimizes the uncertainty and thus, ensures an effective solution.

Further, the authors in [7] employed fuzzy logic to predict green purchase behavior of customers. The results obtained by authors in [7] established that the green purchase behavior of customers can be predicted using social, emotional and conditional values. Thus, the study can support marketing personnel to devise appropriate policies and strategies by employing fuzzy set qualitative comparative analysis. The research is carried forward in multiple directions by various researchers. For instance, Authors in [3] suggest employment of fuzzy logic to address market trends in the fashion industry, a fast evolving industry.

Here, authors have suggested recording the non-purchasing behavior of customers by analyzing in-store behavior of customers through the Internet of Things which was not possible to record previously. This captured data regarding non-purchase behavior is forwarded to the cloud where a fuzzy logic approach is developed to analyze the purchase behavior which can be used to recommend products so as to have efficient supply chain planning.

The efficiency of fuzzy model for mathematical model in an uncertain environment is also witnessed in [16]. Here, authors develop a new method for group decision-making problems considering multiple attributes in an uncertain environment. The approach also considers the attitude of decision maker towards risk. The authors in [16] propose a mathematical model based on interval-valued fuzzy soft set to rank the various alternatives. The applicability of proposed approach is advocated by a numerical example. The competence of fuzzy model to propose a mathematical model in an uncertain environment is also strengthened by work of authors in [18, 19].

3 Proposed Mamdani based FES

As mentioned in the introduction, each commercial organization strives hard to understand the customer's choice and likings to sustain this cut-throat competition in current scenario. For the same, authors in this paper present a Mamdani-based fuzzy model that assists to understand the customer's purchase behaviour and thus, aids him in decision making in an uncertain environment. A detailed understanding of customer behaviour enables business entities to plan accordingly. For the sake of understanding, authors here consider the purchase behaviour of laptop through e-commerce for the purpose of illustration.

3.1 Objective

The objective of the proposed model is to devise a Mamdani-based fuzzy inference model that helps customers to purchase a product in uncertain environment. For the same, an integrated approach is required to understand the behaviour of customers during online purchase. This behaviour is analysed for laptop purchase with respect to various factors viz. Brand, Processor, RAM, Storage, Screen size and Graphics. The model aims to analyse the impact of these factors on purchase decision of customers.

3.2 Participants

The proposed model for purchase behaviour considers participations of young age group who are frequent buyers of electronic gadgets. For the same, survey of UG and PG students of engineering and management from ICFAI Foundation for higher education, Hyderabad, India is conducted with permission of the concerned authorities. This survey is conducted in the class room where students were informed about the purpose of the study. A total of 464 participants in the age group of 19–30 years [male = 279, average age (male) = 25.08 years, female = 185, average age (female) = 23.24 years] are involved in this study. Prior to their participation, the subjects were informed about the opportunity to cooperate in a study related to selecting a laptop as E-commerce product for personal use. Informed consent was sought, and those who signed the informed consent form were the participants in this study. The Questionnaire consisted of twenty questions having 5 point Likert scalefrom strongly agree (5) to disagree (1). Apart from Likert scale, some questions also had binary responses (yes/no). Authors attempt to a give a brief introduction to the FES in the following subsection.

3.3 Fuzzy Expert System

Fuzzy logic is used to analyse the unknownand multi-factorial issues. It can be demonstrated by following block diagram as shown in Fig. 1. The description of basic blocks is as follows:

Fuzzifier module: This module takes the crispinputs and transforms it to linguistic variables.

Rule base: This module contains a library of rules in the form of 'IF–THEN'.

Defuzzifier: It performs the conversion of obtained crisp value to a linguistic term using some defuzzification methods.

Inference Engine: This engine searches the rule base to select the appropriate rule to be executed. Here, in the proposed approach, authors use Mamdani type inference engine. The characteristics of Mamdani-based fuzzy inference system are presented in Table 1.

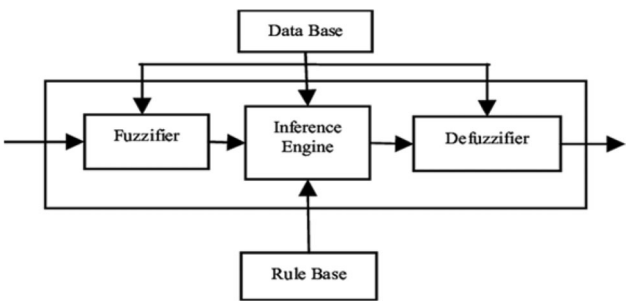


Fig. 1 Block diagram of FES

Table 1 Characteristics of fuzzy inference system Mamdani Model

Operation	Operator	Role	Formula
Sum (OR)	MAX	T-conorm	$\mu C(x) = \max(\mu A(x),\ \mu B(x)) = \mu A(x) \vee \mu B(x)$
Subscription (AND)	MIN	T-norm	$\mu C(x) = \min(\mu A(x),\ \mu B(x)) = \mu A(x) \wedge \mu B(x)$
Implication	MIN	T-norm	$\max(\min(\mu A(x),\ \mu B(x)))$
Aggregation	MAX	T-conorm	
Defuzzification	Centroid		$COA = Z = \frac{\int z\mu(z)dz}{\int \mu(z)dz}$

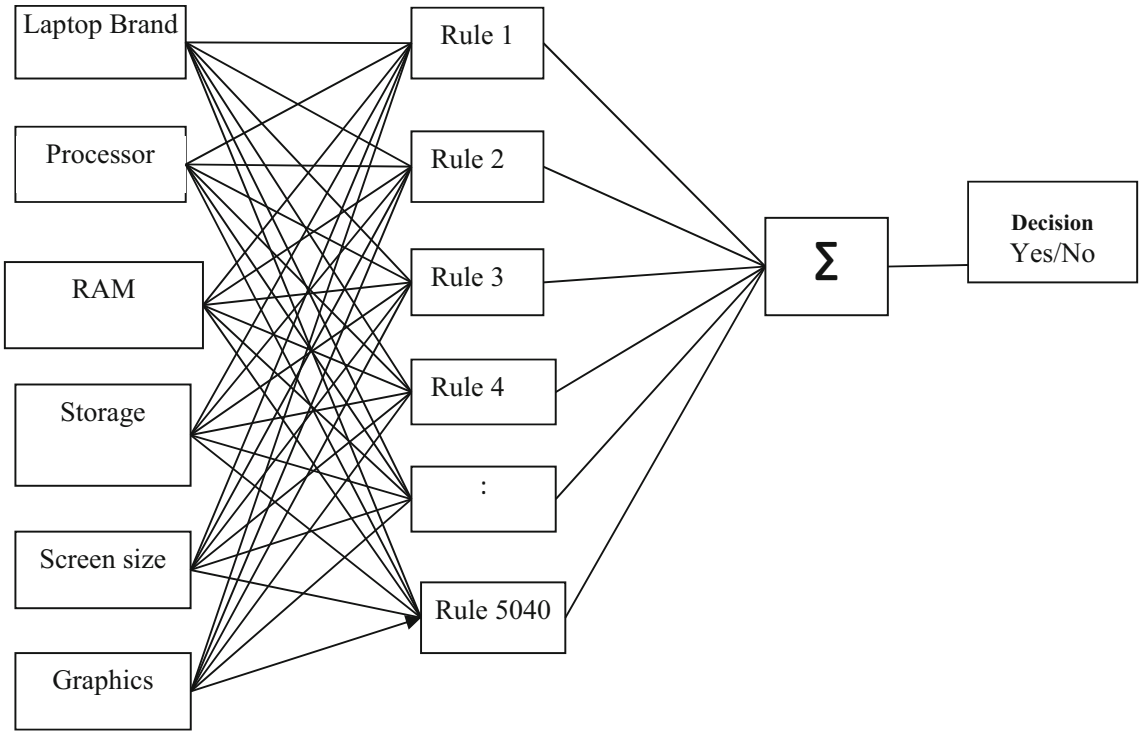


Fig. 2 Fuzzy pattern to calculate purchase value

3.4 Fuzzy Variables and Membership function in FES

Fuzzy linguistic approach provides a way to represent linguistic terms in natural evaluation procedure. A fuzzy linguistic variable is represented using a fuzzy number and hence can also be represented by a fuzzy set. A fuzzy set A represents two things—the first one is the input element x and the second element is the member function value $\mu_{\mathrm{A}}(X)$ (ranging from [0, 1]) as given below.

$$\mathrm{A} = \{(\mathrm{x}, \mu_A(X)) : \mathrm{x} \in \mathrm{X}\}. \tag{1}$$

For the input and the output values, triangular membership functions are used to keep the design of Fuzzy logic. A degree of overlapping is used as shown in Eq. 2. Furthermore, a discourse of normalised to the range [0.0 1.0] is used and the value is called membership value or degree of membership that quantifies the grade of membership of the element in X to the fuzzy set A.

$$\mu_A(X) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{m-a}, & a < x \le m \\ \dfrac{b-x}{b-m}, & m < x < b \\ 0, & x \ge b \end{cases} \tag{2}$$

Table 2 Fuzzy classification of various input and output parameters

	Parameters	Membership functions						
	Brand	Dell	HP	Asus	Lenovo	MacBook		
	(5)	[0.0 0.3]	[0.1 0.4]	[0.3 0.6]	[0.4 0.8]	[0.6 1.0]		
	Processor	Bad	Fair	Excellent	Poor	Adequate	Good	
	(6)	[0.0 0.2]	[0.1 0.3]	[0.2 0.5]	[0.3 0.6]	[0.5 0.7]	[0.6 0.9]	
I/P	RAM	VVLOW	VLOW	LOW	Medium	High	VHigh	VVHigh
	(7)	[0.0 0.2]	[0.1 0.3]	[0.2 0.5]	[0.3 0.6]	[0.5 0.7]	[0.6 0.9]	[0.7 1.0]
	Storage	LOW	Medium	High	VHigh			
	(4)	[0.0 0.4]	[0.2 0.6]	[0.4 0.8]	[0.6 0.9]			
	Screen size	Small	Medium	Large				
	(3)	[0.0 0.3]	[0.3 0.6]	[0.60.9]				
	Graphics	Yes	No					
	(2)	[0.0 0.5]	[0.5 1.0]					
O/P	Purchase value	Yes	No					
		[0.0 0.5]	[0.5 1.0]					

In this equation a, b, and n are real numbers. a and b are the upper and lower bounds of A respectively and m is the median of A.

3.5 Working Principle of Fuzzy Logic Controller (Mamdani approached)

A fuzzy logic controller consists of a set of rules in the form of IF and THEN. Here, antecedent is a condition and the consequent is a control action for the system. Both the antecedent and consequent of the IF–THEN rules are represented using linguistic variables. As the inputs of FRBSs is given by the fuzzy sets, input terms are fuzzified. The output of a fuzzy logic controller is always fuzzy. Hence, method of defuzzification is used to get the corresponding value. The fuzzification of input variable involves the following steps:

- Measure all the input variables
- Perform scaling on the input variables so as to map its range into corresponding universes of discourse.
- Perform fuzzification that converts the input variables into linguistic values, which can be viewed as the label of fuzzy sets.

The rule base is designed on the basis of domain knowledge and information being collected from the survey. Thus, the survey provides required information to design and controls the rules involving linguistic terms. A method of defuzzification is used to obtain the values corresponding to fuzzified output. In this study, fuzzification is utilised as follows:

$$U'_{f\prime} = \frac{\sum_{j=1}^{p} A(\alpha_j) f_j}{\sum_{j=1}^{P} A(\alpha_j)},$$

where $U'_{f\prime}$ is the output of the controller, $A(\alpha_j)$ denotes the firing area of jth rule, p is the total number of fired rules and f_j represents the centre of the area.

3.6 Implementation of the Proposed Model

This proposed model is based on Mamdani Fuzzy approach. It uses six input variables and produces one output variable. The inputs to the proposed model are Brand, RAM, Screen size, storage capacity, Processor and Graphics. The output variable of the proposed model is purchase decision (Yes/No) as demonstrated in the following Fig. 2. The model is implemented in MATLAB2013b.

The following Table 2 demonstrates the all input and output parameters in the proposed model. As evident from Table 2, there are 6 input and 1 output parameter in the proposed model. The range classifications for each input and output variable is also demonstrated in the table. The number of membership ranges for each input variable is written along with in the parenthesis. Hence, the size of rule base becomes $5 \times 6 \times 7 \times 4 \times 3 \times 2 = 5040$ rules that is also demonstrated in Fig. 2.

As discussed earlier, there are 5040 rules in the proposed FES. Rules are the cores of the Fuzzy Rule Based System that represent the relationship between the input and output variables in form of antecedent and consequent. In this problem there are six input variables and each of the

input variables are represented using linguistic terms resulting into 5040 fuzzy rules. For instance, a rule may be as follows:

IF X_1 is Dell AND X_2 is Excellent AND X_3 is VLow AND X_4 is Medium AND X_5 is Large AND X_6 is Yes THEN output is Yes.

Such 5040 rules for the proposed fuzzy expert system are illustrated in following Table 3.

4 Results and Findings

Fuzzy tool was developed with the help of Matlab using 6 input variables 'Brand', 'Processor', 'RAM, 'Storage', 'Screen size' and 'Graphics'. The model produces one output variable using a set of 5040 rules. The following 3-D surface view graphs represent the purchase decision (Yes/No) in the range of 0 to 1 with respect to two input variable only. For instance, Fig. 3a represents the 3-D surface view for purchase decision along company name and Graphics. Now, it is evident from Fig. 3a that the purchase decision becomes higher when graphics has values beyond 0.5 irrespective of the CName. However, it gets very low for the Graphics having a value below 0.5. Similarly, purchase decision along processor and graphics is illustrated in Fig. 3b. The following Figure demonstrates the 3-D surface view for pair of two input variables. From Fig. 3c, it becomes evident that the purchase behavior is for RAM value higher than 0.5. Thus these 3-D surface view represent the purchase behavior of customers for a pair of input variables.

5 Conclusion and Future Scope

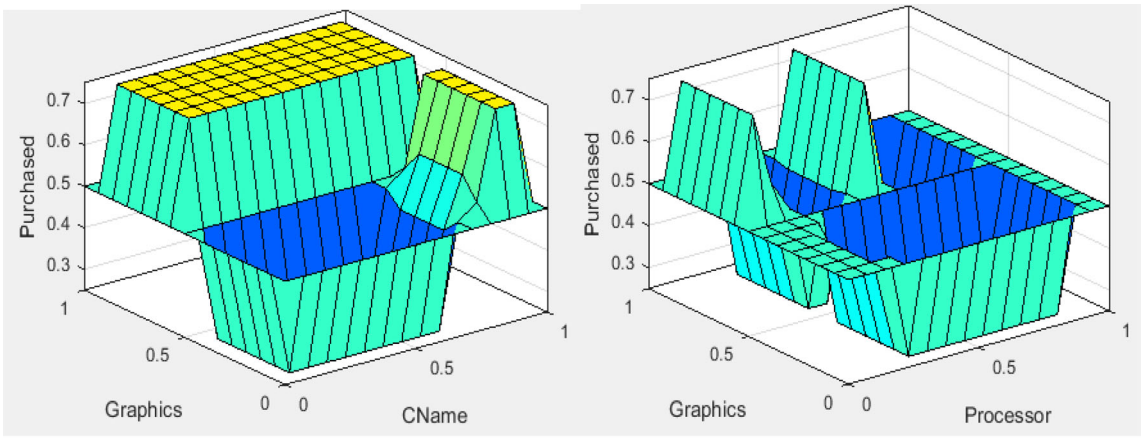
The digital information technology has created ample of opportunities for carrying out online commercial services. So, people prefer to do online shopping as it is comfortable, suitable and trustworthy. But on the other hand the said platform providing ecommerce services are getting assisted with lot of bewilderments, qualms as well as overfilling with outsized product information. So developing a decision support system carrying out online purchase is the need of the hour. Such system also intends to minimize the stated problems by generating customized information based on consumer's specific requirements. In the present paper, authors have designed a Mamdani based Fuzzy mathematical model to assist a personalized digital ecommerce environment. The experimental results rationalize the usefulness and effectiveness of the proposed system. Thus, such mathematical model is going to be a huge help to a user for purchasing e-commerce product.

As the Ecommerce Industry has undergone flabbergasting evolution with the reflective slash of digital Information technology. A comprehensive understanding of customers purchasing behavior with respect to the product attributes, the surrounding ecological, communal as well as emotional factors may help to achieve a successful ecommerce business platform. Hence, the work can be extended further so as to include more number of product attributes. It may also be extended so as to focus on the sentiments, economical and situational attributes as inputs for diverse age groups across geographical diversity so as to build a reliable, customer specific, digitized Ecommerce business platform.

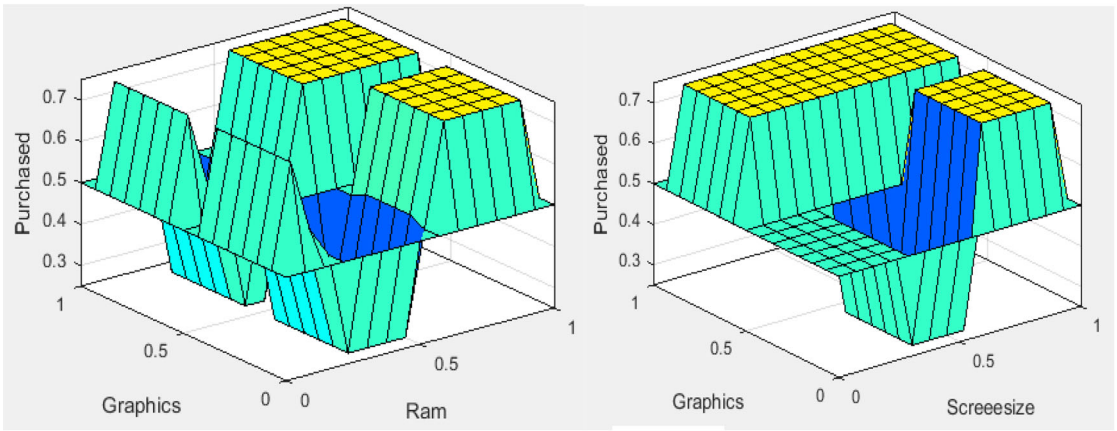
Table 3 Rule base for fuzzy expert system

Brand	Inputs parameter					Output
	Processor	RAM	Storage	Screen size	Graphics	Purchase value
HP	Bad	Small	vvlow	Low	Yes	Yes
Asus	Bad	Small	vvlow	Low	Yes	Yes
Lenovo	Bad	Small	vvlow	Low	Yes	Yes
MacBook	Bad	Small	vvlow	Low	Yes	No
Dell	Fair	Small	vvlow	Low	Yes	Yes
HP	Fair	Small	vvlow	Low	Yes	Yes
Asus	Fair	Small	vvlow	Low	Yes	Yes
Lenovo	Fair	Small	vvlow	Low	Yes	Yes
MacBook	Fair	Small	vvlow	Low	Yes	No
HP	Bad	Small	vvlow	Low	Yes	Yes
Asus	Bad	Small	vvlow	Low	Yes	Yes
:	:	:	:	:	:	:
:	:	:	:	:	:	:
Dell	Good	Large	VVhigh	Vhigh	No	Yes

The proposed model is successfully implemented and the result of the same is discussed in the subsequent section



(a): Cname vs Graphics **(b)**: Processor vs Graphics



(c): Ram vs Graphics **(d)**: Screen size vs Graphics

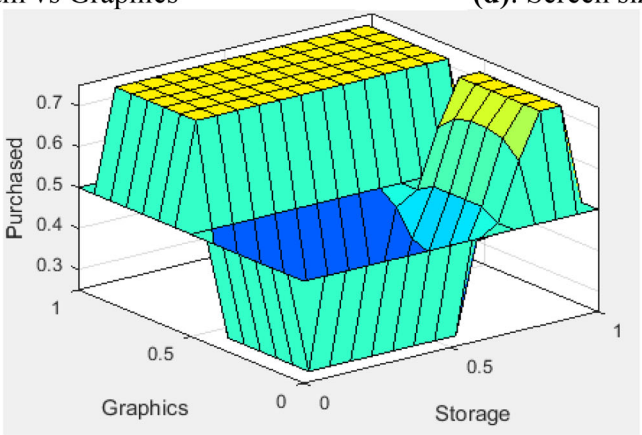


Figure 3 **(e)**: Storage vs Graphics

Fig. 3 **a** Cname vs graphics, **b** processor vs graphics, **c** Ram vs graphics, **d** screen size vs graphics, **e** storage vs graphics

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