

Fuzzy Expert System for Identifying the Physical Constituents of a Human Body

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Abstract

Background/Objectives: As every individual has a distinct combination of Physical Constituents (Vatt, Pitt and Kapha), understanding this individuality is the essence of diagnosis and treatment in Ayurveda. The proposed work is a stepping stone in this field. **Methods/Statistical Analysis:** A fuzzy logic based expert system is designed to calculate the physical constituents (VATT, PITT and KAPHA) of a human body. All the required parameters are finalized after consulting an Ayurvedic Expert during knowledge acquisition phase. **Findings:** The system is implemented using the Fuzzy Logic Toolbox of MATLAB. The accuracy and veracity of the system is evaluated by comparing the outputs of different defuzzification methods. Data collection is performed by survey method and results were highlighted as true and false after verifying from expert. Maximum results depict that the outputs produced by the proposed system matches with those of Ayurvedic Expert. **Application/Improvements:** The proposed system will guide the physicians to provide the personalized treatment to their patients. This fuzzy based system will prove itself as a learning kit for Ayurveda and Vedic practitioner.

Keywords: Fuzzy Logic, Inference System, Knowledge Base, Prakriti, Physical Constitution

1. Introduction

Ayurveda is an ancient science of healing diseases of individuals. Ayurveda is a blend of two words 'Ayur' which signifies life and 'Veda' which signifies science. Therefore the term Ayurveda connotes 'Science of Life'¹. The origin of Ayurveda is native to the Indian subcontinent and was discovered thousands of years ago. Ayurveda says that every individual is different from each other and hence the prescription for every individual should be personalized. Therefore, Ayurveda considers not only the examination of diseases but also focuses on the examination of the patients as well². The most prominent and important method for the examination of patients is Prakriti Prakisha (Examination of Physical Constituents)^{3,4}, literary refers to "Nature". When referring to humans, Prakriti is the unique physical and psychological nature of body⁵. Prakriti is genetic in nature as it is determined at the time

of conception and never changes throughout the life. A human body is made up of five elements namely Water, Fire, Earth, Air and Space and these elements are responsible for some activities in a human body as described in Table 1⁶.

These five elements are represented in human bodies by three physical energies known as "Dosha" in Ayurveda as shown Figure 1. :

- Vatta Dosha (Combination of Air and Space)
- Pitta Dosha (Combination of Fire and Water)
- Kapha Dosha (Combination of Earth and Water)

The different ratio and proportion of these elements determine the Physical Constituents (Vatt, Pitt, Kapha) of an individual which performs various metabolic and psychological functions in the body. The state of their balance is the state of health whereas their imbalance causes diseases. An AI based computer model to diagnose the

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Table 1. Five Elements and their representation in human body.

Five Elements	Representation in Human Body
Water	Represents Blood, fluid, lymph and other fluids and responsible for their transportation
Fire	Responsible for all the transformations and metabolic activities such as digestion, balance of body temperature, transformation of the power.
Earth	Represent the solid structures such as bones, teeth, nails, hair, muscles, cartilage, skin etc.
Air	Responsible for the respiratory system, energy in the nervous system, movement of all the tissues and cell functions.
Space	The whole body is enclosed in space. It represents all the empty spaces in the body like channels, pores, etc.

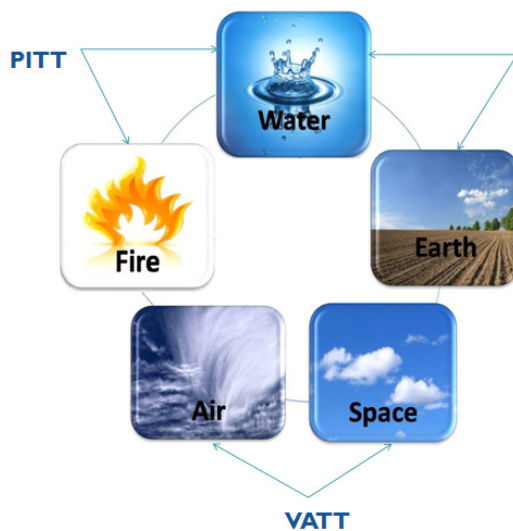


Figure 1. Five elements and physical constituents.

human constituents⁷, as developed but its efficiency was only 77%. Therefore, there is a need to develop a system which could effectively, automatically and accurately calculate the Physical Constituents of the patients.

2. Fuzzy Set Theory

Fuzzy set theory given by Zadeh makes use of the linguistic variables and degrees of membership to surmount the imprecise and uncertain human

reasoning in decision making processes. A fuzzy set can be defined as a group of elements together with their degree of membership. This degree of membership depicts the degree of truth with which a fuzzy element is present in a fuzzy set⁸. Consider a set A of elements x as defined in Eq. (1)

$$A = \{x \mid x > n\} \tag{1}$$

A membership function can be defined as given by following Eq. (2)

$$\mu_K(x): X \rightarrow [0, 1] \tag{2}$$

Therefore, from mathematical point of view, a fuzzy set with elements x in set A and membership value $\mu_K(x)$ can be represented by Eq. (3):

$$K = \{x, \mu_K(x) \mid x \in A\} \tag{3}$$

After Zadeh' theory, Mamdani in 1974 proposed a fuzzy inference process which make use of linguistic control rules. The four parts of Mamdani FIS system are shown in Figure 2

3. Knowledge Acquisition

The first and foremost step before beginning the fuzzy expert system's development is to identify the factors which will assist to calculate the physical constitution of the body. These factors are gathered through consulting an Ayurvedic doctor as well from the Ayurvedic books. The identified factors are divided into five sub categories as shown in Table 2. Fuzzy Inference Systems (FIS) are developed for each of these subcategories and results are combined to produce the final output.

4. Design Methodology of Proposed System

The proposed system is developed using MATLAB's fuzzy logic toolbox⁸. All the parameters for computing the phys-

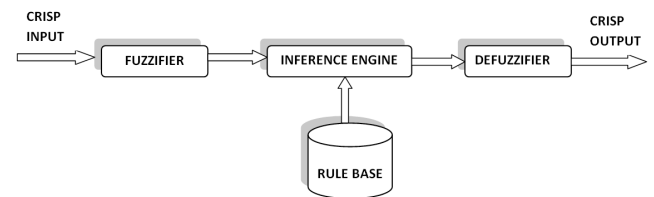


Figure 2. Fuzzy Inference Process.

Table 2. Factors acquired for calculating the Physical Constituents

Category	Sub-Category	Parameters	VATT	PITT	KAPH	Priority Assigned
Physical Traits	Anatomical Traits	Complexion	Dark	Whitish	Fair	Secondary
		Eyes	Small	Moderate size	Big	Secondary
		Hair	Dry	Normal	Soft	Primary
		Physique	Thin	Medium	Heavy	Secondary
		Skin	Dry & Rough	Medium	Oily	Primary
		Tendons & veins	Visible	Fairly Visible	Covered	Secondary
	Physiological traits	Voice/Speech	Stammering & weak	High Pitch	Strong & deep rooted	Secondary
		Sexual Activeness	Less	Medium	High	Secondary
		Eating habits	Fast	Medium	Slow	Secondary
		Walk	Swift	Medium	Slow	Secondary
		Appetite	Changeable	Heavy	Less and regular	Primary
		Stool	Dry and constipated	Loose stool and regular	Thick and sluggish constipation	Primary
	Homeostatic traits	Immunity	Low	Medium	High	Secondary
		Cold tolerance	Very Less	Medium	High	Secondary
		Energy	Low	Medium	High	Secondary
		Sweating	Less	More	Medium	Primary
		Sleep	Irregular & disturbed	Moderate	Sound & deep	Primary
		Thirst	Changeable	Excessive	Less	Primary
Mental Traits	Behavioral Traits	Activities	Hyperactive	Moderate	Slow, Measured	Primary
		Jealous	More	Moderate	Less	Secondary
		Friendship	Short lived	Medium	Strong & long lived	Secondary
		Patience	Less	Medium	High	Secondary
		Talk	Talkative & garrulous	Medium	talk to the point	Secondary
		Temper	Sometimes	Short tempered	Calm & Quiet	Primary
	Intellectual Traits	Concentration	Low	Medium	Good	Secondary
		Intelligence	Low	Moderate	High	Secondary
		Memory & retention	Short	Moderate	Long	Primary
		Grasping power	Medium	High	Low	Secondary

ical constituents are acquired by conferring the experts. Intuition method is used to select the Membership Functions for each of the factors which are then fuzzified and a pertinent knowledge base is constructed⁹. For implementing the system standard Max-min Mamdani inference process has been used. The system is defuzzified by applying the centroid method. The complete methodology of the proposed system is outlined in the following Figure 3.

4.1 Selecting the Membership Functions

Choosing the membership functions is the most important task as it determines the efficiency of the system. Proposed system uses intuition method for selecting the membership functions. Trapezoidal and triangular membership functions are chosen for input and output variables. A trapezoidal membership function can be depicted by $\mu(x; i, j, k, l)$ as shown in Figure 4. and defined as Eq. (4).

$$\mu(x; i, j, k, l) = \max\left(\min\left(\frac{x-i}{j-i}, \frac{l-x}{l-k}\right), 0\right) \quad (4)$$

Similarly the triangular membership function can be depicted by $\mu(x; i, j, k)$ shown as in Figure 5. and defined as following Eq. (5):

$$\mu(x; i, j, k) = \max\left(\min\left(\frac{x-i}{j-i}, \frac{k-x}{k-j}\right), 0\right)$$

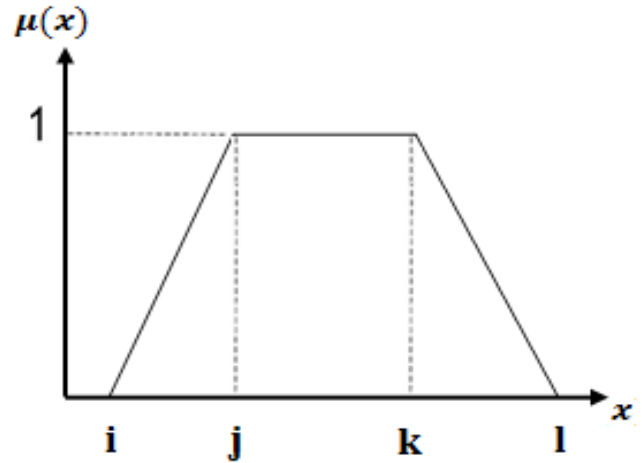


Figure 4. Trapezoidal Membership Function.

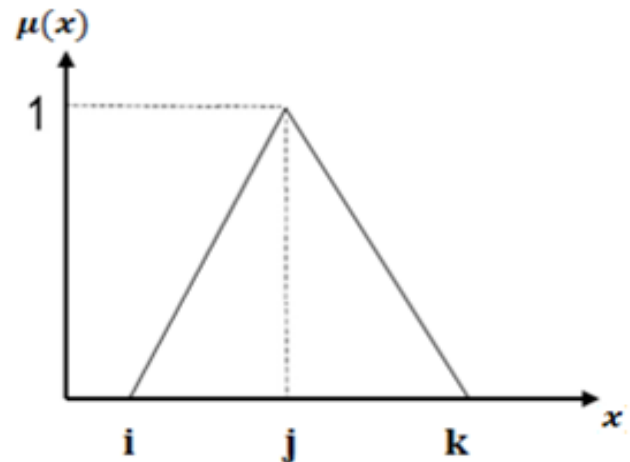


Figure 5. Triangular Membership Function.

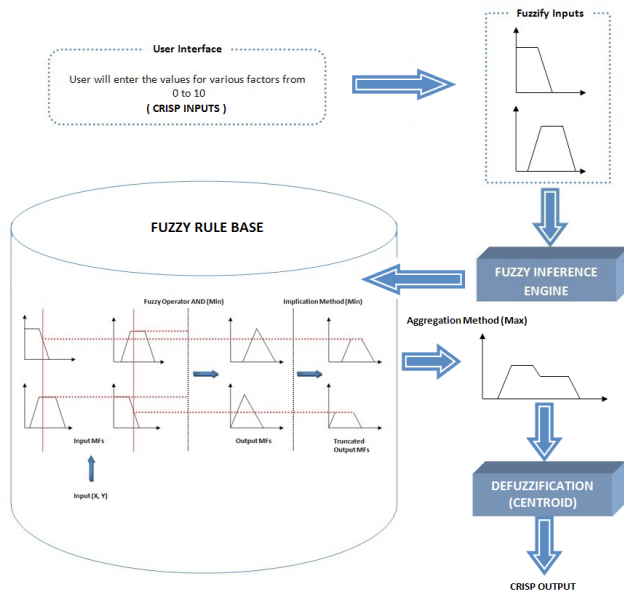


Figure 3. Design Methodology of Proposed System.

4.2 Fuzzification of Input and Output Variables

After identifying the parameters, the next step is to fuzzify these input values. Fuzzification is a way of converting the crisp inputs into fuzzy membership values¹⁰. All the input variables have two trapezoidal and one triangular membership function as depicted in Figure 6 whereas the output variables have two triangular and one trapezoidal membership function as depicted in Figure 7. The fuzzy sets of input and output variable and their ranges are described in Table 3 and Table 4 respectively.

4.3 Fuzzy Rule Base

Next step after the fuzzification is to construct the fuzzy rules. The rules constructed for the proposed system are

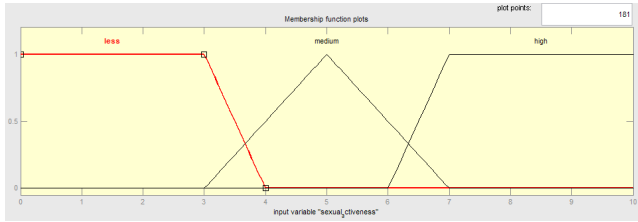


Figure 6. Fuzzification of input variables.

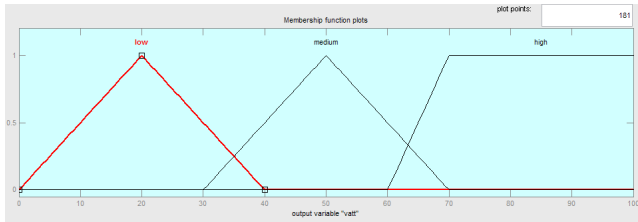


Figure 7. Fuzzification of Output variables.

Table 3. Fuzzy Linguistic Input variables along with their membership ranges

Fuzzy Linguistic Input variables	Membership function ranges(0-10)		
	LOW	MEDIUM	HIGH
	-1-4	3-7	6-11

Table 4. Fuzzy Linguistic Output variables along with their membership ranges

Fuzzy Linguistic Output variable	Membership function ranges(0-100)		
	LOW	MEDIUM	HIGH
VATT	0-40	30-70	60-110
PITT	0-40	30-70	60-110
KAPHA	0-40	30-70	60-110

in IF-THEN format introduced^{11,12}. The IF-THEN rules are represented as:

IF (condition 1 AND condition 2 AND.....condition n) THEN (do something)

Fuzzy rules form the knowledge base of a fuzzy expert system. Fuzzy expert system makes the decisions based on these rules. Fuzzy rules for the proposed system are constructed by consulting the Ayurvedic expert. Some of the sample rules for determining the physical constituents are shown below:

- IF (voice/speech is stammering_&_weak) AND (sexual_activeness is less) AND (eating_habits is slow) AND (walk is slow) AND (appetite is less_&_regular)

AND (stool is dry_&_constipated) then (VATT is medium)(PITT is low)(KAPH is medium)

- IF (voice/speech is stammering_&_weak) AND (sexual_activeness is less) AND (eating_habits is slow) AND (walk is slow) AND (appetite is less_&_regular) AND (stool is thick_&_sluggish_constipation) then (VATT is low)(PITT is low)(KAPH is high)

Figure 8, Figure 9. shows the fuzzy rules and surface view of the rule base.

4.4 Fuzzy Inference Process

For the proposed system Mamdani Inference system has been used as it is the widely used fuzzy methodology. The process given by Mamdani is represented through following Eq. (6) and Figure 10.

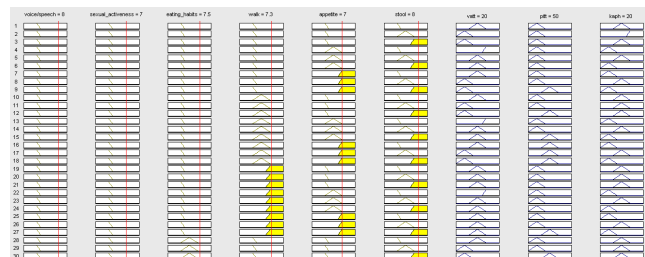


Figure 8. Fuzzy Rule Base.

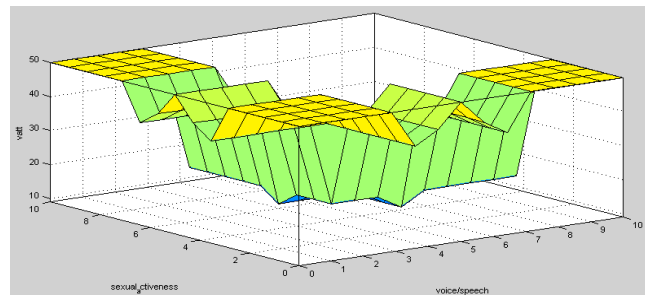


Figure 9. Surface view of rule base.

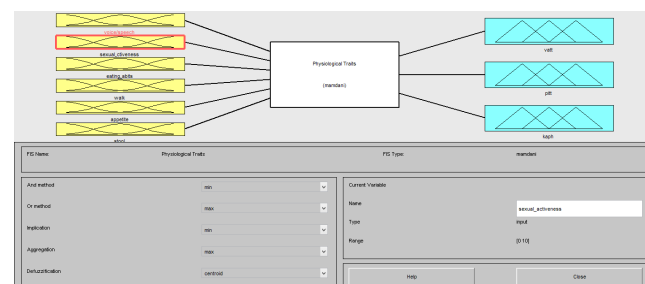


Figure 10. Mamdani's Fuzzy Inference Process.

$$f_C(z) = \frac{\max}{k} [\min [f_A(\text{input}(i)), f_B(\text{input}(j))]] , k = 1, 2, 3 \dots \dots n \quad (6)$$

4.4.1 Fuzzy Operators

Fuzzy operators (AND, OR) are applied to combine two or more fuzzy linguistic variables. The fuzzy intersection (AND) and fuzzy union (OR) operators applied on two fuzzy sets M and N aggregates two membership functions as described in Eq.(7) and Eq.(8) respectively:

$$\mu_{M \cap N}(x) = \min(\mu_M(x), \mu_N(x)) \quad (7)$$

$$\mu_{M \cup N}(x) = \max(\mu_M(x), \mu_N(x)) \quad (8)$$

4.4.2 Implication Method

There are chances that for the same output membership function many rules will be active and selection of only a single membership value is necessary. Minimum input value is picked up if an AND operation is used between inputs when that rule will be active. Similarly the maximum input value is selected when an OR operation is used between inputs and its membership value will be evaluated as membership value of the output for that rule. This is known as implication method. This process is repeated for every rule for determining the output membership functions.

4.4.3 Aggregation Process

The next step after implication method is to combine the outputs of each rule which are different fuzzy sets into a single fuzzy set. This process is referred as the aggregation process. The input to the aggregation process is a list of truncated output functions produced by the implication process for every rule and output is a single fuzzy set.

4.5 Defuzzification

Aggregated fuzzy set is defuzzified to obtain a single crisp output value¹³. LOM, SOM, MOM, Centroid and bisector are five of the built in defuzzification methods in Matlab. The proposed system is defuzzified using the Centroid method as defined in Eq. (9).

$$Z_{COA} = \frac{\int \mu_A(z)zdz}{\int \mu_A(z)dz} \quad (9)$$

After obtaining results using centroid method, all defuzzification methods are applied and outputs are compared to assure accuracy of the system as shown in Table 5¹⁴.

5. Diagnostic Power of the System

A survey is done and data of 20 patients were collected by filling the questionnaires. A part of the 28 questions mentioned in the questionnaire are shown in Figure 11.

The proposed fuzzy expert system is then tested to check whether the output generated by the system matches with the answers of Ayurvedic expert. Table 6 shows test results for the sample data of patients. Maximum results obtained through the system matches with the expert's opinion.

6. User Interface

User Interface for the system is developed such that an excel sheet of inputs for calculating the Physical Constituents is imported and displayed on the click of 'Browse' button as shown in Figure 12 Excel sheet contains all the parameters required to calculate the physical constituents. The user has to enter the values from 0 to 10 in the excel sheet. For example, for skin type user can enter between 0 to 3 if his skin is rough, 4 to 6 if his skin is normal or 7 to 10 if his skin is oily. Computed values of physical constituents are then displayed on the interface.

6.1 Explanation for Computed Physical Constitution

The system also provides the user with explanation facility. On the click of 'Explanation' tab the system will provide the information regarding the dominant constituent type in an individual. Also the user can get to know about the possible diseases an individual can suffer from and dietary recommendation according to the dominant constituent type of the user. Figure 13 shows the dominant constituent type of the user and the dietary recommendations according to the dominant constituent type.

7. Discussion and Conclusion

The proposed system is developed to facilitate the physicians to determine the Physical Constituents (Vatt, Pitt and Kapha) of individuals with more veracity which will help them to prescribe the appropriate medicine according to dominant constituent type to their patients. Therefore, this system could be used as a tool which can assist the Ayurvedic doctors as well as a learning and educative system for the Ayurvedic Medical students. Also even a layman

Table 5. Defuzzified Values of Different Defuzzification Methods for Different Inputs

INPUTS (Physiological Traits)	Voice/Speech		1	2.2	3	5	5.6	6.5	7.5	8	9.4
	Sexual Activeness		1.5	2.7	3.5	4.5	5.1	6	6.5	7	8.4
	Eating Habits		2	3.2	4	4	4.6	5.5	7	7.5	8.9
	Walk		1.8	3	3.8	4.5	5.1	6	6.8	7.3	8.7
	Appetite		1	2.2	3	4.2	4.8	5.7	6.5	7	8.4
	Stool		2	3.2	4	5.5	6.1	7	7.5	8	9.4
Defuzzified values according to different defuzzification methods	MOM	VATT	50	50	20	20	20	20	20	20	20
		PITT	20	20	20	50	50	50	50	50	50
		KAPH	50	50	50	20	20	20	20	20	20
	SOM	VATT	50	46	8	10	10	10	10	20	20
		PITT	20	16	8	40	40	40	40	50	50
		KAPH	50	46	38	10	10	10	10	20	20
	LOM	VATT	50	54	32	30	30	30	30	20	20
		PITT	20	24	32	60	60	60	60	50	50
		KAPH	50	54	62	30	30	30	30	20	20
	CENTROID	VATT	50	45.4	20	20	20	20	30.8	20	20
		PITT	20	20	32	50	56.4	62.1	44.8	50	50
		KAPH	50	54.9	50	20	20	20	20	20	20
BISECTOR	VATT	50	48	20	20	20	20	27	20	20	
	PITT	20	20	29	50	53	58	46	50	50	
	KAPH	50	52	50	20	20	20	20	20	20	

Questions	Answer the questions below on a scale of 0 to 10 as mentioned on the right side of each question	Patient ID:	Name :	Age :
1				
2	What type of Hair do you have?	Dry (0-3)	Normal (4-6)	Soft (7-10)
3	What type of Skin do you have?	Dry & Rough (0-3)	Medium (4-6)	Oily (7-10)
4	What type of Physique do you have?	Thin (0-3)	Medium (4-6)	Heavy (7-10)
5	How are your Tendons & viens?	Visible (0-3)	Fairly Visible (4-6)	Covered (7-10)
6	How is your Complexion?	Dark (0-3)	Wheatish (4-6)	Fair (7-10)
7	What is the size of your Eyes?	Small (0-3)	Moderate size (4-6)	Big (7-10)
8	How much Sexually Active you are?	Less (0-3)	Medium (4-6)	High (7-10)
9	How are your Eating habits?	Fast (0-3)	Medium (4-6)	Slow (7-10)
10	How is your Walk?	Slow (0-3)	Medium (4-6)	Swift (7-10)
11	How is your Appetite?	Less and regular (0-3)	Changeable (4-6)	Heavy & uncontrollable (7-10)
12	What is your level of Immunity?	Low (0-3)	Medium (4-6)	High (7-10)
13	What is your level of Cold tolerance?	Very Less (0-3)	Medium (4-6)	High (7-10)
14	What is your Energy level?	Low (0-3)	Medium (4-6)	High (7-10)
15	How much do you Sweat?	Less (0-3)	Medium (4-6)	More with foul smell (7-10)
16	How is your Sleep?	Disturbed (0-3)	Moderate (4-6)	Sound & deep (7-10)
17	How is your Temper?	Calm & Quiet (0-3)	Sometimes (4-6)	Hot & short tempered (7-10)

Figure 11. A Part of the Questionnaire.

who doesn't have any knowledge of Artificial intelligence can use this system to identify his constituent type.

This research work can further be extended by considering more factors that are responsible for evaluating the Physical Constituents. The system could be tested on more number of patients. Also this system could be developed as an application based on Neuro-Fuzzy technique.

8. Acknowledgements

The authors would like to acknowledge the expert Dr. Rajbyot Kaur who works as Ayurvedic Medical Officer

Table 6. Sample Test Results for Fuzzy Inference System for Calculating Physical Constitution

Serial No.	PATIENT ID	OUTPUTS			RESULT	
		Physical Constitution (Given by System)				Physical Constitution (Given by Expert)
		VATT	PITT	KAPH		
1	P_01	27.15	50.69	22.15	PITT	True
2	P_02	25	30	45	KAPH- PITT	True
3	P_03	33.92	47.26	18.81	PITT-VATT	True
4	P_04	27.77	22.65	49.56	KAPH	True
5	P_05	23.88	40.55	35.55	PITT- KAPH	True
6	P_06	42.18	38.96	18.84	VATT- PITT	True
7	P_07	44.48	22.69	32.81	VATT-KAPH	True
8	P_08	28.84	52.30	18.84	PITT	True
9	P_09	30.55	40.55	28.88	PITT-VATT	True
10	P_10	23.88	33.88	42.22	KAPH- PITT	True
11	P_11	37.77	44.44	17.77	PITT-VATT	True
12	P_12	52.30	23.84	23.84	VATT	True
13	P_13	16.58	41.70	41.70	PITT- KAPH	True
14	P_14	47.26	33.92	18.08	VATT- PITT	True
15	P_15	24.95	55.08	19.95	PITT	True

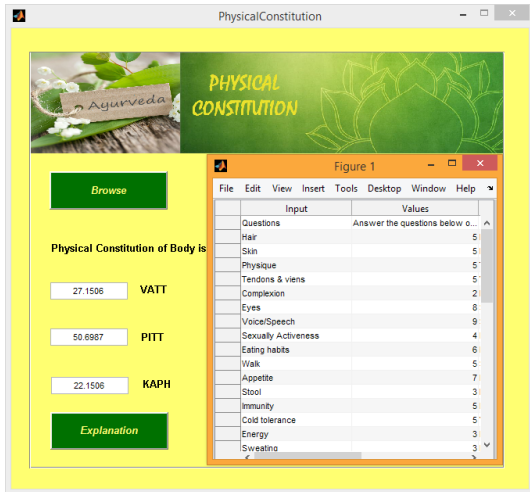


Figure 12. User Interface for Calculating Physical Constituents.

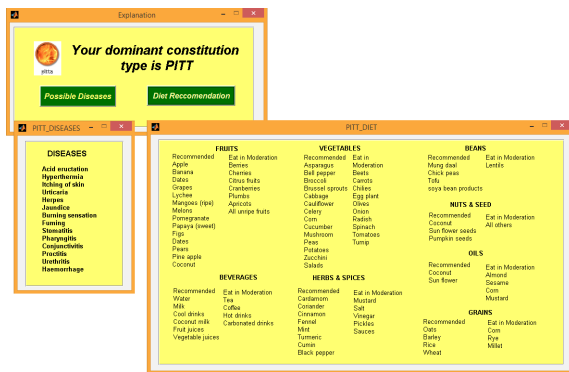


Figure 13. Explanation for Computed Physical Constitution.

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