

APPLICATION OF FUZZY LOGIC IN SMART AGRICULTURE TO RECOGNISE TOMATO FRUIT RIPENESS

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ABSTRACT

The tomato is a fruit that is widely used in modern life for cooking. It is helpful not just in terms of the means of subsistence it offers for farmers, but also in terms of the health advantages it delivers. Tomatoes are also high in lycopene and vitamin C. Lycopene has been demonstrated in studies to reduce the hazard of osteoporosis, cancer, as well as treat male infertility. Smart agricultural technology allows for the making of tomato plant whether it is in period of season or not. This research focuses on the fruit's look since it is the most essential factor in determining how profitable a product will be as a commercial item. Only as the tomato matures will its beautiful beauty and high quality be revealed. Because surface colour is strongly related to maturity, visual identification is a valid approach to measure tomato maturity. Green, breakers, changing, pink, light red, and red stages are the six phases of tomato colour development. The scholars utilised the colour, size, and form of tomato fruit to estimate maturity using fuzzy logic in the context of smart farming.

Keywords: Tomato, fuzzy logic, shape index, membership function

1. Introduction

Globally, the tomato crop is crucial. It is advantageous not just for the means of subsistence it delivers to the farmers but also for the well-being benefits it brings. A meagre 163.9 million tonnes of tomatoes were produced in 2020, yielding an average of 34.7 tonnes per hectare [1]. There are several uses for tomatoes. When fully grown, the fruit may be bottled whole or processed into puree, paste, powder, ketchup (tomato sauce), sauce, and soup. Pickled or served as an appetiser, unripe ones might be utilised. Various illnesses may be treated with tomatoes as well. In world wide, traditional medicine employs the use of tomato extract to treat a range of illnesses. While tomato may be used to treat edoema during gestation, dried berry hot water extract can be used to cure ulcers, wounds, haemorrhoids, and burns. Fresh fruit may be utilised to cure liver and kidney diseases as well as aid with digestion. Additionally rich in lycopene and vitamin C are tomatoes [2]. Lycopene has been shown to minor the risk of osteoporosis, breast and prostate cancer, and to cure male infertility. Similar to other vegetables, tomatoes may be classified according to their quality based on their appearance, texture, safety, flavour, and nutritional value. The appearance is the most significant quality since it affects the creation's marketing potential [3]. Only when the tomatoes reach maturity will their appealing appearance and great quality be satisfied. Because surface colour is closely connected to tomato maturity, using visual identification to assess tomato maturity is a practical strategy [4]. The six stages of tomato colour maturation are green, breaking, changing, pink, pale red, and red. Additionally, the present literature often selects three maturity levels (developed, half-developed, and undeveloped phases) [5]. Because of this, the researcher absolute to carry out a study that would concentrate on identifying tomato maturity. There are two types of tomatoes: determinate and indeterminate [6]. Because they produce all at once and have little bushes, deciduous tomato plant like Roma are termed to as "bush" tomatoes. They are good for cooking as well as canning. Better Boy and Celebrity are examples of indeterminate tomato varieties that produce throughout the growing season. Compared to determinate tomatoes, which have a shorter lifespan and a more compact height, unknown tomatoes may develop to 12 ft. tall and have a maximum lifespan.

Two distinct tomato plant types are crossed in a hybrid tomato plants to create a refined variety that has traits from together of its paternities. Genomic material from various distinct tomato kinds is used to develop the seeds that result in hybrid tomato plants [7]. Cross-pollinated flowers produce fruit that gives rise to plants that have advantageous features from both of their parents. Both seeds and vegetative propagation may be used to create hybrid tomato plants. Vegetative propagation produces a new vegetable that is similar to its parental plant by utilising a section of the hybrid plant that has been removed. The benefits of hybrid tomato cultivars over open-pollinated species are many. Hybrids often provide greater yields and develop more consistently and quickly [8]. Numerous hybrids have enhanced fruit excellence and resistance to disease. Due to benefits, many agriculturalists still opt to plant hybrid seeds despite of the increased seed prices. There are a lot of well-known tomato seed vendors in the Philippines, namely Condor and Eastwest. As a consequence, more

agriculturalists are beginning to plant cross tomatoes due to their superior flavour, quick growth, and higher yields [9].

The Atlas F 1 tomato seed provided by Condor Supplier was chosen by the researcher. It is a novel hybrid variety that has a high level of resistance to the damaging yellow leaf disease. It was created at Allied Botanical, the first herbal plant seed business entirely owned by Filipinos, investigation and refinement amenities [10]. The Atlas F1 is renowned for its exceptional tolerance to the nation's many tropical climates, tremendous prolificacy, and prolonged harvesting life.

Table 1 Type of tomato used for the study

Variability	Colour	Dimensions	Outline
Atlas	Orange red	Huge	Oval



Fig. 1 Atlas tomato

2. Fuzzy system

Fuzzy logic is a decision-making technique that, according to studies, functions likewise to humanoid switch logic. It is a practical strategy because it describes inputs and outcomes in human language and offers a straightforward way to draw a deduction from uncertain, murky, or ambiguous input data. A fuzzy-rule set is used in fuzzy-logic systems to characterise the connection between the input and output variables. Also, conclusions drawn from a minor sample of data may be quite correct. When utilising a "if-then" or "and" and "or" expression, a fuzzy rule is produced. In the illustration below, a fuzzy logic system is shown in action, with the fuzzifier using the clear inputs to start the designated rules before the de-fuzzifier produces the output. To determine if a tomato is fully ripe, somewhat mature, or immature, look at its colour, size, and form.

3. Result and Discussion

The study is based on the arrival and features of the Atlas F 1 diversity to assess whether or not the growing tomato is ripe, as stated in Table 1. Colour, size, and shape are all criteria considered in the research. Table 2 illustrates the likely tomato combinations colour. The dimensions of the tomato are described in table 3. Determining the relation of the obtained equatorial width to the polar diameter and dividing by the equatorial diameter will give you the most precise and accurate description of the tomato's shape. This percentage is referred to

as an "index number" is illustrated in table 4. However, the following is the definition of "shape index":

$$\text{Shape Index: } \frac{\text{Equitorial diameter}}{\text{Polar diameter}}$$

Table 2 Possible combinations of tomato colour

Colour	Explanation
Green	Combination of light and dark
Turning	Less than 30% pink, red or tarnish-yellow
Breaker	Not 10% of pink, red or tarnish
Light red	60% red
Red	90% red

Table 3 Dimensions of tomato

Size	Diameter (Cm)	
	Min	Max
Minor	6.4	6.9
Average	7.2	07-Aug
huge	8.1	8.8
Extra huge	9	9.6

Table 4 Shape index number

Index shape	Number of the index
Round	1.5
Oval	1
Oblate	2.1

The fuzzifier receives these three variables as input. The fuzzy logic develops rules to detect whether the tomatoes are ripened, somewhat developed, or undeveloped after fuzzifying the inputs and it is shown in table 5, 6 and 7.

Table 5 Fuzzy logic determine ripeness

Colour	Dimension	Texture	Ripeness
Light red	average	Circle	Ripe
red	huge	oval	Ripe
red	extra huge	Circle	Ripe
red	average	oval	Ripe
red	huge	Circle	Ripe
red	extra huge	oval	Ripe
red	average	Circle	Ripe
Light red	huge	oval	Ripe
Light red	extra huge	Circle	Ripe
red	average	oval	Ripe

Light red	huge	Circle	Ripe
Light red	extra huge	oval	Ripe
red	average	Circle	Ripe
red	huge	oval	Ripe
Light red	extra huge	Circle	Ripe

Table 6 Fuzzy logic determine unripens

Colour	Dimension	Texture	Ripeness
Light red	average	Round	Unripe
pink	huge	oval	Unripe
pink	extra huge	Round	Unripe
Light red	average	oval	Unripe
pink	huge	Round	Unripe
Light red	extra huge	oval	Unripe
pink	average	Round	Unripe
pink	huge	oval	Unripe
Light red	extra huge	Round	Unripe
pink	average	oval	Unripe
Light red	huge	Round	Unripe
pink	extra huge	oval	Unripe
pink	average	Round	Unripe
Light red	huge	oval	Unripe
pink	extra huge	Round	Unripe

Table 7 Fuzzy logic determine undeveloped

Colour	Dimension	Texture	Ripeness
green	average	Round	Undeveloped
breaker	huge	oval	Undeveloped
green	outsized	Round	Undeveloped
breaker	average	oval	Undeveloped
green	huge	Round	Undeveloped
breaker	outsized	oval	Undeveloped
green	average	Round	Undeveloped
breaker	huge	oval	Undeveloped
green	outsized	Round	Undeveloped
breaker	average	oval	Undeveloped
green	huge	Round	Undeveloped
breaker	outsized	oval	Undeveloped
green	average	Round	Undeveloped
breaker	huge	oval	Undeveloped
green	outsized	Round	Undeveloped

The tomato fruit's coloring, shape, and geometry were among the input functions used in the research as shown in figure 3. The output purpose is the ripeness of the fruit. The values utilized in these membership functions were obtained from numerous plant research.

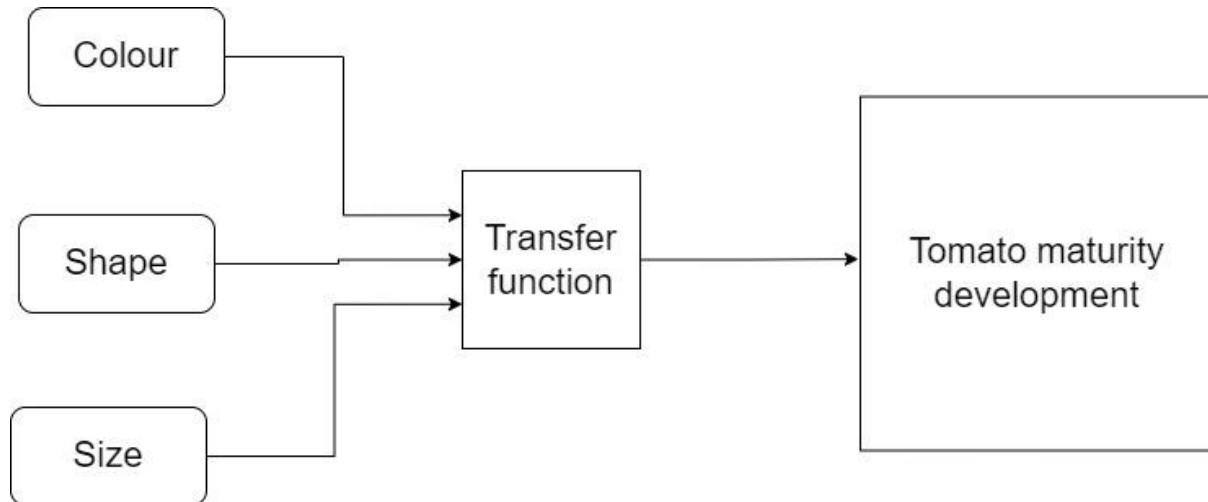


Fig. 3 Input and Output function

MATLAB is used to simulate Tomato development Recognition by Fuzzy Logic. The study made use of Superficial Viewer, a 3-D curve that shows how tomato colour, size, and shape are linked to maturity output. Increasingly, this arc depicts a two-input, one-output scenario. Like Shape vs. Size, Color vs. Size denotes that both inputs have a significant impact on maturity. Color, however, seldom affects shape.

The study will make use of the hybrid and semi-determinate tomato cultivar Atlas Fl. Atlas F 1 tomatoes are oval-shaped, average in size, and reddish-orange in colour when fully grown. According to the study, the tomato fruit's size and colour are better indicators of ripeness than its form. As it grows, its size and colour become more precious. Green, break, turn, pink, light red, and red were some of the colours used. The colour changes from pink to crimson as the fruit ripens. The sizes were minor, average, huge, and outsize. Average to extra-huge tomatoes may range in size when grown correctly. They came in oblate to spherical shapes. A mature tomato should have an oval or circular shape.

Conclusion

In this research the maturity state of tomato fruits is evaluated using fuzzy logic. There are many techniques used in the machine learning approach, but the three inputs of tomato fruit colour, size, and shape—which are based on theoretical and scientific values—were the main focus of this study. Maturity monitoring can be done once the tomato plant starts to leaf. The technique used in the research may also be used to evaluate the plant development.

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