International Journal of Control and Automation
Vol.7, No.1 (2014), pp.27-38
http://dx.doi.org/10.14257/ijca.2014.7.1.03

Application of Ultrasonic and Fuzzy Logic to Determine Fruit Maturity Level

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Abstract

In this research, has been done the next usage of ultrasonic and fuzzy logic to determine fruit maturity level. Reflection of ultrasonic with different frequency are used to measure water content and fruit texture in other side fuzzy logic are used to determine the fruit maturity level depend on water content and fruit texture. The research was limited to avocado, mango and papaya. Sample of data obtained by measure 30 fruit of each kind and test it with laboratories to calibrate and also test it with human perception to prove the fact of maturity. The result of this research is device that can transmit ultrasonic signal then read the reflection of it and MatLab application to fuzzy logic processing. Accuracy and precision analyzing give the result that the system have a good accuracy and precision with low condition of error rate. However, analyze give not good condition of precision for the percentage of maturity level. Analyze with statistic calculation give the result that there is a strong and linear correlation between water content and fruit texture with the level of fruit maturity. The research found that the fruit in mature condition is not always having sweet taste and also the opposite.

Keywords: *Ultrasonic, fuzzy logic, water content, texture, maturity*

1. Introduction

Fruit is an excellent food for the human body. Many vitamins are contained within the fruit which was no doubt needed by the human body. While, the human body cannot produce the vitamin by itself. Therefore, fruit is absolutely needed for the human body. Vitamin content of the fruit is not always in good condition. It is determined by the conditions in the consumption of fruit. The condition of the mature fruit has a very good vitamin. Fruit in the condition that should be consumed by the human.

The problem that occurs is many times the consumption of fruit not in ripe condition. This condition will affect the vitamins contained in the fruit. Thus, the vitamin that obtained to the body is not to be optimal. At the other sides, consuming not mature condition of the fruit will give not good taste of it. However, many people are paying less attention to the maturity level of fruit that is consumed.

Of these problems, the authors think to make a research method that is used to knowing the fruit maturity level. This method uses an ultrasonic signal which was developed in its use and also the fuzzy logic is developed to analyze the results obtained. It is useful to get good fruit quality. Thus, vitamin obtained will be better.

The purpose of the study was to determine the use of the ultrasonic signal and a fuzzy logic as a method that can measure the maturity of fruit. This study only uses 3 kinds of fruit, the avocado, mango and papaya. The three kinds of fruit have been

ISSN: 2005-4297 IJCA

chosen because thoose fruits have changes in water content and texture when mature. The end result of this research is a device that is able to transmitte ultrasonic signal with different frekensi and a MatLab applications that use fuzzy logic to perform calculations of fruit maturity level.

2. Method

In measuring the level of fruit maturity, its used water content and texture of fruit as variable to calculate the level of fruit maturity. Both of these variables were reflect the level of fruit maturity. "Texture features are found to contain useful information for quality evaluation of fruit and vegetables, e.g., classification of grade of apples after dehydration with the accuracy of 95%, and prediction of sugar content of oranges with a correlation coefficient of 0.83"[1]. From these quotations can be seen that the texture of the fruit reflects the degree of dehydration of the fruit. It can be seen also that the texture of the fruit has a lot of the information contained therein. The quote also gives the sense that the changes texture of the fruit can determine the quality of the fruit. For example, by looking at the texture of the fruit can be measure the level of the water content in the fruit. Fruits that contain lots of water means that the fruit is ripening in Events. Thus, we can get the fruit with good quality and very good vitamins contained.

"The high frequency ultrasonic characterization provides a high spatial resolution for local measurements of speed and attenuation in the orange peel. The strong attenuation of ultrasounds in the peel has restricted our study only to the flavedo-layer instead of the whole peel-thickness. For this reason the obtained results differ to those previously published especially for the longitudinal speed. For the measurements of the attenuation coefficient, the results are in agreement compared to those already published. This method can be employed to study the differences of the water content in the peel with the age i.e. the analysis of the hydration state of the peel like a decisive criterion to detect the maturity degree of orange fruit"[2]. The quote explains that by relying on the reflection of ultrasonic signals transmitted to the fruit, we can get the water content level of the fruit then we use that to determine the maturity level of the fruit. This means that the fruits will contain lots of water when ripe and also will change the texture of the fruit because of water contain.

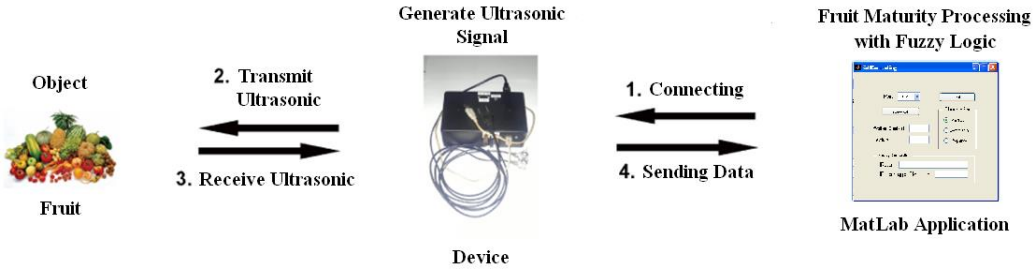

Figure 1. Fruit maturity measuring schema

Obtained from these two quotes, it is possible to measure the level of fruit maturity from water content and texture of the fruit. To measure these two variables used ultrasonic signals. Ultrasonic signals was chosen because these signals do not damage

or contaminate the media propagated or reflecting. However, the determination of fruit maturity also requires the help of fuzzy logic to calculate the probability level of fruit maturity.

3. Ultrasonic

Ultrasonic signal is a voice signal with frequency more than the frequency of human hearing, more than 20kHz. In this study used two different frequencies to determine water content and texture of the fruit. In measuring the water content of the fruit used ultrasonic signal with a frequency of 45 KHz, while to measure the texture of the fruit used ultrasonic signal with a frequency of 35 KHz. Both of these frequencies can not be heard by humans. Frequency has also been used in papers that discuss the level of watermelon maturity[3]. But, the frequency used is still at the frequency of human hearing.

Like the sound signals, ultrasonic signals can be propagated and reflected in the media. The resulting amplitude in receiver will always be different from the transmitter that propagated by the media or reflecting. "Gelombang ultrasonik dapat merambat dalam medium padat, cair dan gas. Reflektivitas dari gelombang ultrasonik ini di permukaan cairan hampir sama dengan permukaan padat, tapi pada tekstil dan busa jenis gelombang ini akan diserap"[4]. It is proved that ultrasonic signal can be propagated in the media.

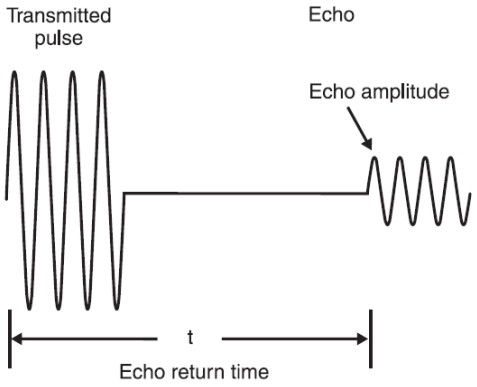

Figure 2. Illustration of reflecting ultrasonic signal

"When a short pulse of transmitted ultrasound is scattered from a small sample volume of moving blood and an echo signal from that volume is detected by a transducer, two pieces of information are obtained: A very accurate measurement of the time taken for the echo to return to the transducer, The amplitude (size) of the echo signal, *i.e.*, the size of the pressure fluctuations in the echo"[5]. From quotations can be seen that the ultrasonic signal have amplitude when its reflected. Amplitude can be defined as how strong the signal is. By the amplitude from reflected ultrasonic signal, we can determine the level of fruit maturity.

4. Fuzzy Logic

Fuzzy logic is a form of probability calculations in the digital side, which the results obtained are not only logic true or false, 1 or 0, in electric it can be said 5V or 0V. Fuzzy logic can provide the results of logic between true or false using the rules that

apply to fuzzy logic. This is useful in determining the maturity of the fruit, because fruit maturity is not necessarily linear, although there are some sections that describe the linear relationship that reflects the maturity of the fruit based on the water content and texture of the fruit.

Fuzzy logic has many types in use. In this study, fuzzy logic is used type mamdani. Fuzzy logic mamdani was chosen because its have very good in accordance with the state reflect the actual reality of life. “Mamdani method is widely accepted for capturing expert knowledge”[6]. The statement explained that the fuzzy logic mamdani have a broad level of suitability for complex data. This is consistent with the measurement obtained from the fruit maturity level.

5. Device Design And Application

Device built using microcontroller ATMEGA8 as the central processing of the device. Microcontroller ATMEGA8 chosen because of its small size but large capacity. microcontroller combined with a usb to serial interface to make the device can be accessed using the usb port. This is due to the rare computer that has a serial port interface. The power supply used is 220V and convert it to low voltage using transformer. However, the device is also equipped with multiple voltage circuit that function as a DC voltage multiplier. Voltage is multiply to approximately 100VDC. This high voltage is needed because the signal reflections of ultrasonic is too weak. If the gain on the receiver amplifies the signal, will cause the noise to be amplify very strong.

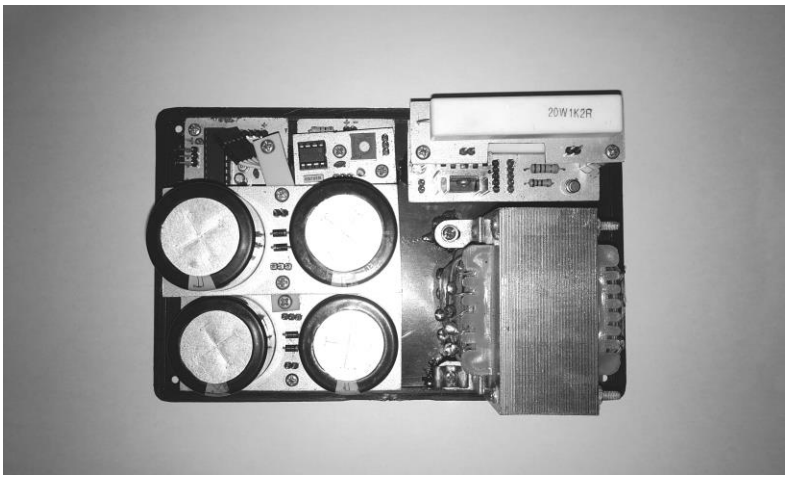

Figure 3. Inside of the device

This will interfere with the reception of the signal. Microcontroller will generate ultrasonic signal alternately 35KHz then 45kHz. Ultrasonic signal will be amplified using transistor BC108 as a buffer with 12V VCE voltage which is then reamplified with power transistor IRF840 using drain voltage of approximately 100V. Then, ultrasonic signal with high voltage is transmitted through an ultrasonic transducer and reflected by the fruit which will be read how high the amplitude of the reflected signal. Ultrasonic signal received by the transducer will be filtered using a band pass filter and amplified with a non-inverting op-amp IC CA3130. Gain of the amplified is 100x from

the input voltage. In the next step, to remove the noise from receive ultrasonic signal is used comparator op-amp so that will eliminate the noise voltage that appears. Its because, noise signal was low. If we put comparator with reference voltage a little higher than noise, we will get only the original signal without noise. The last step is to perform signal processing using analog to digital converting (ADC) to convert the analog voltage into digital data. ADC features already included in the microcontroller so it does not require additional circuits. Then, the digital data is sent through the usb to serial interface into a computer and will be used by the fuzzy logic to process and determine the level of fruit maturity.

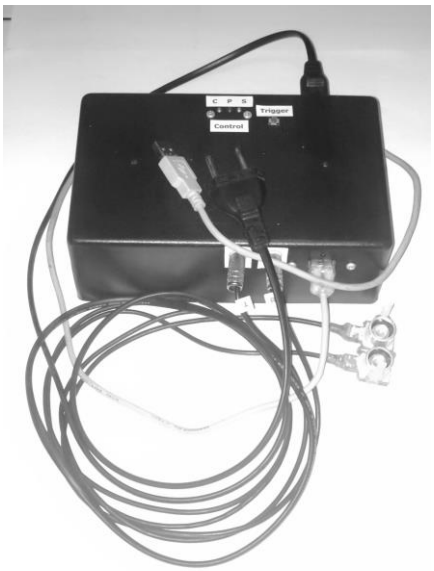

Figure 4. Ultrasonic signal processing device

The application was built using MatLab R2012b. At the MatLab program already has a feature to change the processing of fuzzy logic into a standalone application that can be run on any computer without having a MatLab program. Applications created using programming languages combined with fuzzy logic processing. In measuring the fruit maturity, the selection must be made in advance on the type of fruit you want to see the level of fruit maturity. This is need to be done because there are differences in fuzzy logic to determination of fruit maturity for an avocado, mango and papaya. Here is a rule used in fuzzy logic:

1. If (Texture is hard) and (Water_Content is less) then (Maturity is Before_Mature) (1)
2. If (Texture is hard) and (Water_Content is normal) then (Maturity is Before_Mature) (1)
3. If (Texture is hard) and (Water_Content is more) then (Maturity is Before_Mature) (1)
4. If (Texture is medium) and (Water_Content is less) then (Maturity is Mature) (1)
5. If (Texture is medium) and (Water_Content is normal) then (Maturity is Mature) (1)
6. If (Texture is medium) and (Water_Content is more) then (Maturity is Mature) (1)
7. If (Texture is soft) and (Water_Content is less) then (Maturity is Over_Mature) (1)
8. If (Texture is soft) and (Water_Content is normal) then (Maturity is Over_Mature) (1)
9. If (Texture is soft) and (Water_Content is more) then (Maturity is Over_Mature) (1)

Figure 5. Fuzzy logic rule

The scope of fuzzy logic is obtained from intelligence data that was done before experiments. Data intelligence still gives results in the form of digital data from the device ADC results. This data is used as the input variabel of fuzzy logic.

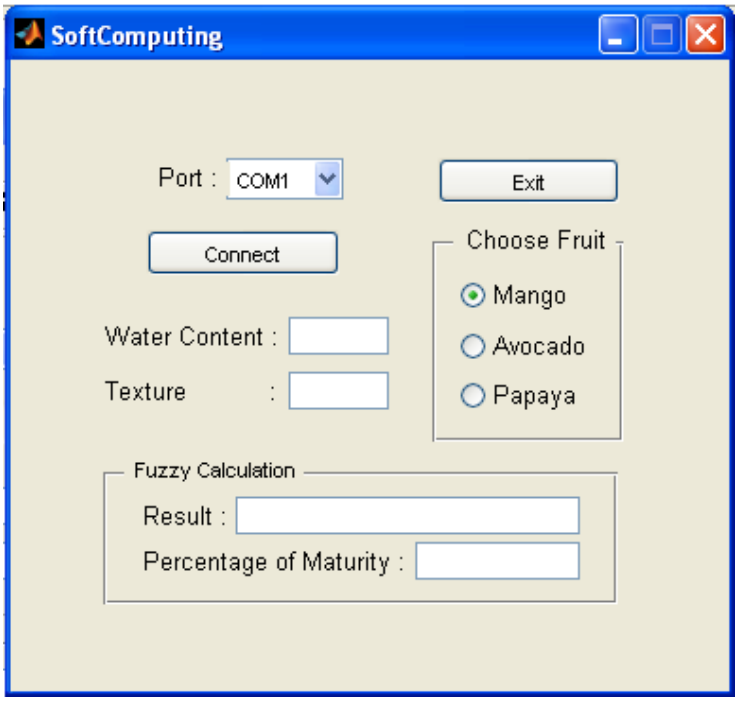

Figure 6. Stand-alone MatLab application

6. Experiments

The research was done by direct measurements on 30 samples for each fruit using device and application. After that, 5 samples for each kind of fruit will have test of a laboratory at Center For Tropical Horticulture Studies, IPB and 25 samples for each kind of fruit will have test using human perception. Measurement with device and application are repeated 10 times with the same sample for the fruit to be a laboratory test and repeated 3 times with same samples of fruit that will be tested using human perception. Thus, obtained 50 measurements for each kind of fruit for laboratory tests and 75 measurements for each kind of fruit for test using human perception. Measurement results using the device and application will be compared with the results from laboratory tests and human perception test. The data comparison will result error rate, accuracy and precision. To see the relationship between water content and texture of the fruit with fruit maturity, SPSS statistical data processing program was used to calculate.

6.1. Error Rate Measurement

Table 1. Error rate measurements

Error Rate Avocado				
Experiment	**Total Measurement**	**Total Error**	**Error Rate (%)**	**Total Error Rate (%)**
Result from Lab IPB	50	10	20	13.33
Human Knowledge	75	5	6.67	

Error Rate Mango				
Experiment	**Total Measurement**	**Total Error**	**Error Rate (%)**	**Total Error Rate (%)**
Result from Lab IPB	50	6	12	10.00
Human Knowledge	75	6	8.00	

Error Rate Papaya				
Experiment	**Total Measurement**	**Total Error**	**Error Rate (%)**	**Total Error Rate (%)**
Result from Lab IPB	50	8	16	12.00
Human Knowledge	75	6	8.00	

Mistake level or better known as error rate, is an evaluation that given to the system to find out how many the error measurement of the system and to know the quality of the system. Error rate calculations is devided for each kind of fruit. This is done to know the error measurement for each kind of fruit. From the table 1, we know that the system has a low error rate. It can be seen from the percentage of error contained in the Table 1.

$$Error\_Rate = \frac{Total\_Error}{Total\_Measurement} \times 100\% \quad (1)$$

6.2. System Accuracy

Table 2. Accuracy measurements

Accuracy of Measuring Avocado				
Experiment	Total Measurement	Accepted Measurement	Accuracy (%)	Total Accuracy (%)
Result from Lab IPB	50	26	52	62.67
Human Knowledge	75	55	73.33	

Accuracy of Measuring Mango				
Experiment	Total Measurement	Accepted Measurement	Accuracy (%)	Total Accuracy (%)
Result from Lab IPB	50	28	56	64.00
Human Knowledge	75	54	72.00	

Accuracy of Measuring Papaya				
Experiment	Total Measurement	Accepted Measurement	Accuracy (%)	Total Accuracy (%)
Result from Lab IPB	50	25	50	65.00
Human Knowledge	75	60	80.00	

Accuracy of Water Content and Texture				
Kind of Fruit	Difference with Lab Test			
	Water Content		Texture	
	Farthest	Nearest	Farthest	Nearest
Avocado	2.79	0.04	0.22	0.01
Mango	3.19	0.04	0.19	0.01
Papaya	2.64	0.03	0.18	0.00

In building a system, keep in mind how suitability of data resulted from the system. This will give good integrity for the data of the system. The value has to be accurate in measurement as calibration of data fitness with measure value. Accuracy of a system is the fitness value of the data resulted by the system when taking measurements. How close the measured data with the reference value is very important. In determining the accuracy of a measurement system, I used the results of laboratory tests for fruit sample. Laboratory tests have a very good level of accuracy so it is very useful as a reference in determining the accuracy of the measurement system. Calculation accuracy of the system are separated by water content, texture and level of fruit maturity. Accuracy of the system is calculated based on each kind of fruit that will be more detil at the accuracy of the system.

From accuracy measurements table, we know that the difference in the measurement of water content and texture is not too far away but for the result of maturity level is not more than 75%. So it can be seen that the accuracy of the water content and the texture is good, while good enough for the level of maturity. Comparison of accuracy only for experiments with laboratory testing. Because, for level of accuracy need a value as the reference. Level of accuracy in the fruit maturity has good enough because of differences in mature or not statement of the fruit through test based on human perception. Because it was found that mature fruit is not always have sweet taste, and

the opposites. For human perceptions only know that mature fruit is always have sweet taste.

6.3. System Precision

Precision needs to be calculated in building a system. Measurement precision of the system is needed to see how consistent the data resulted from the system. Precision is a form of calculation to find out how difference the data resulted in the system each time was measured for the same sample. The more difference resulted in data then the precision level will get lower. Precision calculated for every kind of fruit in order to see the precision of the measurement of each kind of fruit. Calculation precision of the system using samples from laboratory testing and human perception. This is due to the calculation precision of data only see how far of the data spread in each measurement sample. Precision is calculated based on the water content and teksur of fruit.

Table 3. Precision measurements

Precision of Fruits						
Kind of Fruit	Differences of Measurement					
	Water Content		Texture		Maturity	
	Farthest	Nearest	Farthest	Nearest	Farthest	Nearest
Avocado	1.85	0.00	0.20	0.00	49.36	0.00
Mango	2.50	0.02	0.15	0.00	33.18	0.03
Papaya	1.55	0.00	0.10	0.00	24.05	0.00

If we look at the difference in water content, it can be seen that the data is spread out well even though the difference in the range of less than 3 based on average values. So it can be said that the precision of water content measurement in the fruit is quite good. If we look at the difference in texture, it can be seen that the data is spread out better than the water content with the difference in the range of less than 1 based on the average value. So it may be mentioned that the precision of texture measurement in the fruit is very good.

For the fruit maturity level, precision do not acording to classification of fruit maturity, but its acording to percentage value of fruit maturity. This is due to the fruit maturity with percentage 90% - 120% is still classification as mature fruit based on laboratory testing and human perception. If we look at the difference in the maturity column, it can be seen that the spread data is not good enough than the data of water content and texture with the difference in the range of less than 50 based on average values. So it may be mentioned that the precision of the measurement maturity of the fruit that is not good enough.

6.4. Statistic Analysis

SPSS is used to perform statistical data processing. Correlation and regression testing is done to see whether or not the relationship between the water content and texture of fruit maturity.

Table 4. Correlation test result

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.761[a]	.580	.570	9.60277

a. Predictors: (Constant), Texture, Water_Content

From multiple correlation analysis, it can be seen that the value of R is 0.761 close to 1. This means that there is a strong enough relationship between the two independent variables with one dependent variable. By looking at the results of the correlation analysis, it can be concluded that the hypothesis can be accepted, there is a strong enough relationship between changes in water content and texture of the fruit with the level of fruit maturity.

To see how far the relationship between the two independent variables with one independent variable is used multiple regression analysis. This is necessary as a continuation of the correlation analysis and useful to see how far water content and texture of the fruit can affect fruit maturity.

Table 5. Relation test result

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	11066.468	2	5533.234	60.005	.000[a]
	Residual	8022.546	87	92.213		
	Total	19089.014	89			

a. Predictors: (Constant), Texture, Water_Content

b. Dependent Variable: Maturity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-78.011	65.182		-1.197	.235
	Water_Content	2.955	.740	.278	3.993	.000
	Kekerasan	-94.800	9.458	-.697	-10.023	.000

a. Dependent Variable: Maturity

From the results of multiple regression analysis, it was found that the value of sig. <0.05. This may imply that the regression equation can be used to make predictions. So, it can be known that the water content and texture of the fruit can predict the fruit maturity by using regression equation.

$$Y = -78.011 + 2.955(Water\_Content) - 94.800(Texture) \quad (2)$$

7. Conclusions

Ultrasonic signal can be used to determine the water content and texture of the fruit and to determine maturity level of avocado, mango and papaya by using different of ultrasonic frequency. Mamdani fuzzy logic is useful in determining the maturity of the fruit by value of water content and texture of an avocado, mango and papaya. There is a strong linear relationship between water content and texture of the fruit in determining the maturity level of avocado, mango and papaya.

From the results of laboratory testing and human perception, it was found that there were fruit already in a mature condition but the taste of the fruit is not sweet and human perception determine maturity of the fruit only based on the fruit taste.

8. Future Enhancement

As for some of the good done for the development of advanced research. Using ultrasonic sensors that have better sensitivity level, so that the result will be a more detail measurement. Adding more variables such measurements to calculate the levels of sugar in the fruit to make level of fruit sweetness can be calculated and will be better in determining the fruit maturity.

Creating a smart device that does not require matlab fuzzy logic to determine the level of fruit maturity. This can be achieved by storing fuzzy result data from MatLab on the device, so for the future measurement can refer to the data and dont need MatLab anymore. It makes the device running alone when measuring and determining the fruit maturity. Obviously, it is necessary to start training the device to make the device has knowledge when determine the fruit maturity.

Acknowledgements

My sincere thanks goes to Center For Tropical Horticulture Studies, Bogor Agricultural University, who have given their time and attention in helping this research.

A special note of thanks to Dr. Ford Lumban Gaol, lecture at Bina Nusantara University, for his expert guidance.

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