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Fuzzy Based Augmented Reality for 3D Image Modelling

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Abstract

In today's world Augmented Reality and Virtual Reality is of prime importance. To create a scenario using Augmented Reality it is important to model objects in 3D space. Once the modelling is complete the Augmented Reality Map could be used in several applications like medicine where 3D bio printing should be done. It could also be used in education and teaching to illustrate complex working mechanisms. Here a fuzzy based algorithm has been proposed to create 3D models of objects for Augmented Reality maps. The Fuzzy rule method reduces RMSE, compared to AR Marker, Fingertips and Checkerboard by 35%, 45% and 21% respectively. The Fuzzy rule method also improves accuracy of resolution of images, compared to AR Marker, Fingertips and Checkerboard by 48%, 11% and 11% respectively.

***Keywords:** Fuzzy Based Modelling, Augmented Reality, Virtual Reality, Bio Printing, 3D rendering, AR Marker, Fingerprint, Checkerboard, RMSE, Variance.*

1. Introduction

Augmented Reality and Virtual Reality is gaining importance in today's world in several domains. Some domains include Medical and Education sector. In Medicine it becomes important for 3D bioprinting of organs. In education sector it is important for illustration of several complex mechanisms.

Augmented Reality uses several SDK (Software Development Kit) tools like Vuforia, Metaio, etc. These tools provide 3D rendering of objects. They also create 3D models based on the perspective drawing created.

In all these models the objects are modeled based on the points of an object usually shown as pixels. These are obtained from camera positions. The points are later modelled as matrices.

PositD.ion of rotation, tilting and transformation are carried out by matrix operations.

The Fuzzy rule method reduces RMSE, compared to AR Marker, Fingertips and Checkerboard by 35%, 45% and 21% respectively. The Fuzzy rule method also improves accuracy of resolution of images, compared to AR Marker, Fingertips and Checkerboard by 48%, 11% and 11% respectively.

The organization of the book chapter is as follows: Section 2 discusses the literature survey, Section 3 explains the proposed algorithm with the salient features of the algorithm illustrated with an example. Section 4 presents the simulation results in detail. Section 5 concludes the work and explains the future directions of extension.

2. Literature Survey

The Augmented Reality algorithms fall under 2 broad categories namely Marker based and Marker less.

In Marker less algorithms, silhouette's are created. Segmentation is carried out in foreground or background as explained by Caseracciu et al in [1]. Cameras are placed at different positions to capture a visual hull of the image. Automation in this model is carried out based on the visual hull.

Augmented Reality also helps in printing and publishing. It makes content dynamic with a higher degree of interactivity. It bridges the gap between the real and virtual world as discussed in [2].

Augmented reality has also been used in accessibility. It attempts to help people on wheelchairs by using an Android User Friendly Interface as discussed by Sanches et al in [3]. It uses a feature named Access in a Touch.

It has also been used to enhance the performance of mobile apps as explained by Chao and Parker in [4]. It uses a technique named SLAM (Simultaneous

Localization and Mapping). Most Augmented reality models use Head-Mounted Displays (HMDs) to obtain interactive 3D real time display as discussed by Azuma in [5].

Markerless motion tracking of awake animals by observing changes in brain by a technique known as Positron Emission Tomography (PET) as discussed by Kyme et al in [6].

Template tracking for Marker less registration has been carried out by 3D registration. It computes frames on the motion of the objects and based on the same it makes correspondences. From these correspondences, it uses illumination insensitive tracking as explained by Lin et al in [7]. Tracking of objects have also been compared analyzing the pros and cons by using strategies fixed template tracking, Illuminative insensitive tracking, etc.

In fixed template tracking is used when the displacement is weak.

Marker less vision based tracking has also been studied for 2D images as explained by Beir and Stichling in [8]. This strategy attempts to extract maximum information from the camera position of the 2D images.

In 3D vision some 2D features are augmented to the perspective of the image. Based on this analysis a hypothesis is created.

3. Proposed Work

In this work, a fuzzy based approach has been proposed to decide the movement of points. Each point has been modelled as a 3 x 3 square matrix to represent x, y and z directions. Depending on the number of vertices the object has the matrices may be formulated. A fuzzy column vector which is chosen for each component namely x,y and z is chosen.

A. Fuzzy Rule Vector

The fuzzy rule vector is formulated by identifying a few factors and these are prioritized. Based on these priorities a vector is created with components as the priority weights.

The position of points is formulated as a matrix which can be illustrated as follows:

A point (x,y,z) could be represented as a matrix as follows

x	0	0
y	0	0
z	0	0

The vertices of an object are taken in clockwise cyclic order of columns. For example if we have 6 vertices P(x1,y1,z1), Q(x2,y2,z2), R(x3,y3,z3), S(x4,y4,z4), T(x5,y5,z5) and U(x6,y6,z6)

The matrix representation of the above points would be as follows:

Point P

x1	0	0
y1	0	0
z1	0	0

Point Q

0	x2	0
0	y2	0
0	z2	0

Point R

0	0	x3
0	0	y3
0	0	z3

Point S

x4	0	0
y4	0	0
z4	0	0

Point T

0	x5	0
0	y5	0
0	z5	0

Point U

0	0	x6
0	0	y6
0	0	z6

The fuzzy rule vector could be represented as follows as a column vector

a
b
c

Where a, b and c are priorities represented as the components of the vector.

The fuzzy vector represents the rule strengths. The fuzzy rule vector is given by the expression

$$FRV = \left(\frac{(3Dmatrix \times RuleVector)}{\sum_{i=1}^{i=n} RuleVectorComponents} \right) \text{-----}\rightarrow(1.1)$$

The salient features of the algorithm is explained below:

- Obtain the number of vertices of the object

for each Vertex

- Obtain the points for the 3D position of the object in space as a matrix

- L1: Convert the 3D position matrix to fuzzy matrix by multiplying the same by a rule strength vector.
- Find the difference between the Target position matrix and the fuzzy rule matrix
- If (difference of any component of vector <= 0) then.
- Retain the fuzzy rule matrix as final position of object in 3D space

else

Repeat the procedure L1
- End the procedure

B. Example

The algorithm working could be explained with an example as follows:

Assume we have an object with 6 vertices and coordinates are as follows P(1,3,4), Q(2,3,4), R(1,3,5), S(1,4,3), T (2,4,1) and U(3,2,1)

Representing as a Matrix P would be

1	0	0
3	0	0
4	0	0

Q would be

0	2	0
0	3	0
0	4	0

R would be

0	0	1
0	0	3
0	0	5

S would be

1	0	0
4	0	0
3	0	0

T would be

0	2	0
0	4	0
0	1	0

U would be

0	0	3
0	0	2
0	0	1

Rule Strength Vector would be

3
1
2

Fuzzy Rule Vector is given by the formulae

$$FRV = \left(\frac{(3Dmatrix \times RuleVector)}{\sum_{i=1}^{i=n} RuleVectorComponents} \right)$$

C. Target Vectors:

TV for P	TV for P	TV for R	TV for S	TV for T	TV for U
1	1	1	1	1	1
1	1	1	3	1	1
1	1	2	2	1	1

Iteration 1:

FRV for P	**FRV for Q**	**FRV for R**	**FRV for S**	**FRV for T**	**FRV for U**
0.5	0.33	0.33	0.5	0.33	1
0.17	0.50	1.00	2.00	0.66	0.66
0.33	0.66	1.66	1.5	0.16	0.33

Difference Vectors:
DV = TV - FRV

DV for P	**DV for Q**	**DV for R**	**DV for S**	**DV for T**	**DV for U**
0.5	0.67	0.67	0.5	0.67	0
0.83	0.5	0	1	0.34	0.34
0.67	0.34	0.34	0.5	0.84	0.67

In the above example iterations could be carried out till any one component of the DV becomes <=0.

This is the constraint for optimality and the object has reached its final position.

4. Simulation Results

The algorithm has been simulated using Unity Vuforia Engine for about 1000 images and the results have been compared with ARTag Marker, Fingertips and Checkerboard algorithms.

The performance has been evaluated based on 2 metrics
- RMS (Root Mean Square) Error
- Variance

A. RMS Error

The RMS error is a measure of identifying the clustering tendency of the difference error obtained. The difference error is the difference between the target and fuzzy rule vector. It is computed using the expression

$$RMSE = \sqrt{\frac{(T\arg etvector - Fuzzyrulevector)^2}{n}}$$

eqn → *(1.2)*

Variance:

The variance is the measure of clustering of the accuracy of images in terms of pixel resolution from highest accuracy. It is given by the following expression

$$Variance = \left(\frac{(Maxaccuracy - averageacaracy)^2}{n} \right)$$

eqn→(1.3)

The comparison of the RMSE of the fuzzy rule method with conventional strategies like AR Tag Marker, Fingerprint and Checkerboard has been indicated in Table I.

The comparison of the variance of the fuzzy rule method with conventional strategies like AR Tag Marker, Fingerprint and Checkerboard has been indicated in Table II.

It could be observed from Table 1 that the average RMSE for AR Marker, Fingertips, Checkerboard and Fuzzy Rule Strength is 52.83, 61.57, 44.33 and 36.31 respectively.

It could be also be observed from Table 1 that the reduction of RMSE for Fuzzy Vs AR Marker, Fuzzy Vs Fingertips, Fuzzy Vs Checkerboard is 35%, 45% and 21% respectively.

It could be observed from Table 2 that the average Variance in Accuracy for AR Marker, Fingertips, Checkerboard and Fuzzy Rule Strength is 51.75, 58.25, 62.40, 67.86 respectively.

It could be also be observed from Table 2 that the Increase in Variance of Accuracy for Fuzzy Vs AR Marker, Fuzzy Vs Fingertips, Fuzzy Vs Checkerboard is 48%, 11% and 11% respectively.

A plot comparing the RMSE for all techniques has been illustrated in Fig 1.

The reduction in RMS error and increase in variance accuracy of resolution has also been plotted for all the above algorithms.

It could be observed that the Fuzzy Rule algorithm reduces the RMS Error to a great extent and improves the variance of accuracy in resolution of images.

5. Conclusion

This work proposes a Fuzzy Rule Strength algorithm which uses a fuzzy vector to handle the movement of the object. It also helps to identify the optimal position of the object. The approach reduces the RMS error and improves the variance in accuracy.

Table I: Comparison of RMSE of Fuzzy Vs other Approaches

Number of Images	RMS Error (pixel)				Reduction in RMS Error (%)		
	AR Tag Marker	Fingertips	Checkerboard	Fuzzy Rule Strength	(Fuzzy Vs AR Marker)	(Fuzzy Vs Fingerprint)	(Fuzzy Vs Checkerboard)
50	21.46	37.45	15.67	10.45	51.30	72.10	33.31
100	25.67	41.56	18.34	13.45	47.60	67.64	26.66
150	32.47	48.67	26.76	18.45	43.18	62.09	31.05
200	43.51	51.45	35.67	23.45	46.10	54.42	34.26
250	51.67	56.78	45.65	36.54	29.28	35.65	19.96
500	58.65	63.45	51.56	43.65	25.58	31.21	15.34
650	64.56	68.56	56.76	48.54	24.81	29.20	14.48
750	72.34	76.87	59.65	51.43	28.91	33.09	13.78
850	76.45	82.34	65.65	57.65	24.59	29.99	12.19
1000	81.56	88.54	67.54	59.45	27.11	32.86	11.98
Average	**52.83**	**61.57**	**44.33**	**36.31**	**34.85**	**44.82**	**21.30**

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Table II: Comparison of Variance of Fuzzy Vs Other Approaches

Number of Images	Variance Accuracy				Increase in Variance Accuracy (%)		
	AR Tag Marker	Fingertips	Checkerboard	Fuzzy Rule Strenth	(Fuzzy Vs AR Marker)	(Fuzzy Vs Fingerprint)	(Fuzzy Vs Checkerboard)
50	15.65	25.67	32.45	41.45	164.86	27.73	27.73
100	23.45	34.56	38.67	45.67	94.75	18.10	18.10
150	34.24	41.56	45.34	51.54	50.53	13.67	13.67
200	38.45	42.54	49.87	55.45	44.21	11.19	11.19
250	45.67	52.43	52.34	58.76	28.66	12.27	12.27
500	52.54	56.47	62.43	68.78	30.91	10.17	10.17
650	61.56	68.46	72.43	76.53	24.32	5.66	5.66
750	76.45	82.65	86.45	89.54	17.12	3.57	3.57
850	81.56	85.74	89.45	92.43	13.33	3.33	3.33
1000	87.89	92.43	94.54	98.45	12.02	4.14	4.14
Average	**51.75**	**58.25**	**62.40**	**67.86**	**48.07**	**10.98**	**10.98**

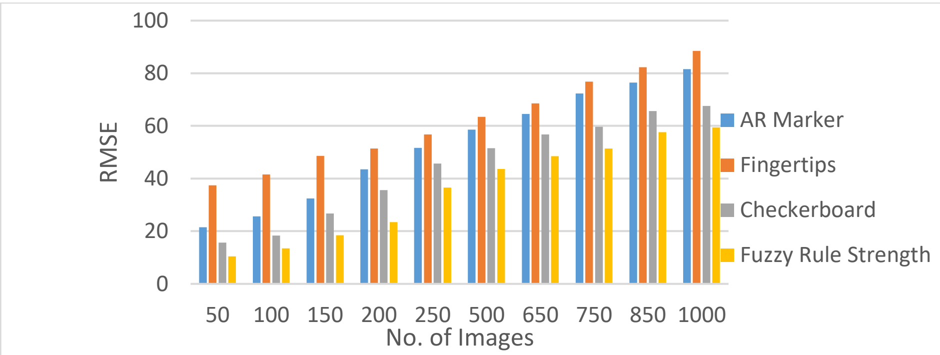

Figure 1: Plot Comparing RMSE of Fuzzy Vs Other approaches

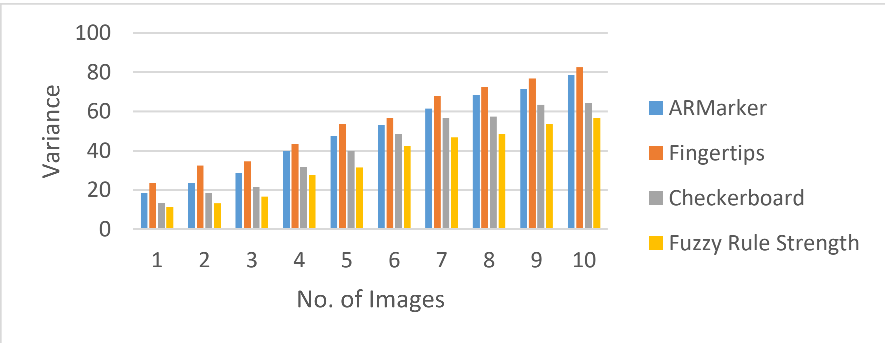

Figure 2: Plot Comparing Variance of Fuzzy Vs Other approaches

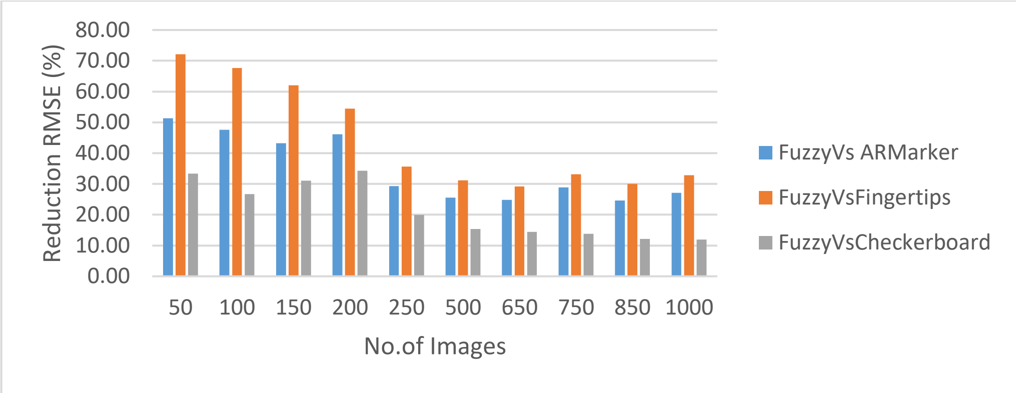

Figure 3: Plot Comparing Reduction of RMSE of Fuzzy Vs Other approaches

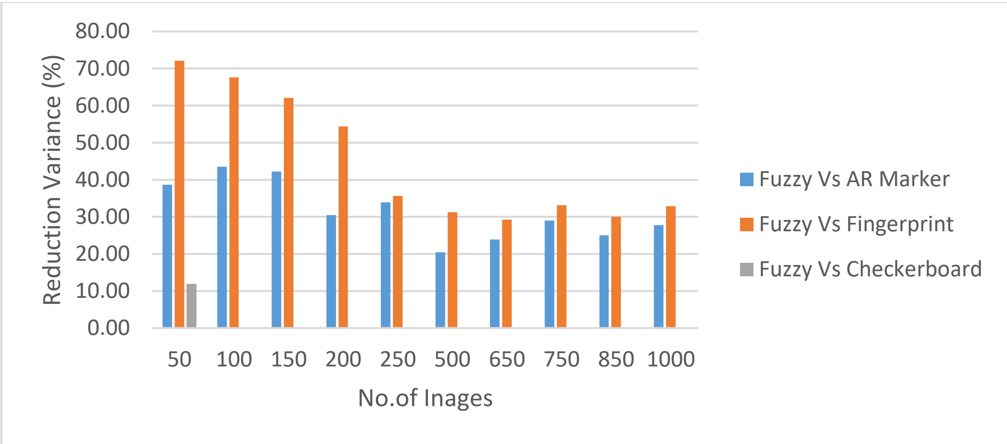

Figure 4: Plot Comparing Reduction of Variance of Fuzzy Vs Other approaches

6. Future Work

The algorithm could be extended in several avenues of bioprinting of organs and teaching techniques in education sector. It could also be used to handle exceptional conditions by modifying the fuzzy rule vector.

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