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Construction of control chart using fuzzy probabilistic approach for cotton sweater product

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Abstract

In this paper, creation of fuzzy statistical control chart using the fuzzy membership function is proposed. It establishes the efficiency of finding to conveyable cause when an out of control signal appears. It is also easy to understand for out of control signals. It illustrates the cotton sweater product of quality evaluation such as color, designs, quality and price of a product with consumer's demographic characters on a hedonic rule.

Keywords: Fuzzy set, Fuzzification, De-fuzzification, Performance measures, Hedonic scale, Cotton sweater.

Introduction

In the modern scientific world manufacturing companies competitions have brought about increasing pressure on the quality. So companies are concerned to undertake quality of color assurance to satisfy their customers. Keeping these in mind, they spend substantial amount of resources for improving their quality. Quality is conformed to the requirements of specifications and it is suitable for use. Thus manufacturing organizations are interested to organize the quality assurance programs, so that 100 % perfection is achieved. However this is not possible in real life. There is some variation in the manufacturing products.

The variation can be classified into two types, namely; transferable causes of difference and possibility causes of difference. Transferable causes of difference are considered to be those that are not part of a process and are correctable without altering the system. Chance causes of difference can be abridged only by altering the fabrication processes. Control charts are broadly used lively techniques to easily checking and examining production processes. They focus on the effort to separate assignable causes of difference. In general, the lessening of chance causes of difference is not necessary and involves extra cost. So it is not practicable to condense the natural difference. However some appropriate statistical patterns of appreciation may describe the causes of variations.

Shewhart has introduced $\bar{X}$ and R control charts. The control charts detect special causes as a versatile, powerful and indispensable instrument with practitioner when dealing with variables data to observe the progression. Shewhart control charts are of immense use to detect assignable causes which are simple to know and speedy to execute. There are no simple techniques to replace them. Numerous new charts have been anticipated to replace the $\bar{X}$ and R charts, such a new control chart as semi-circle control chart for variable data and so on[1].

The modern study of fuzzy logic begin in year 1960 Zadeh has proposed the idea of fuzzy sets and fuzzy algorithms. Mamdani has then unmitigated the concept into what has become a fuzzy logic system. Fuzzy logic is attract a great deal of awareness in the business and industrial world. The fuzzy logic system has been productively launched in Automobile Speed Control, Robot Arm Control, Water Quality Control and habitual Train Operation Systems etc., In order to preserve the typical format of control charts and to assist the process ability plots of annotations on the chart, it is necessary to renovate the fuzzy sets which are connected with the linguistic values into scalars. They will be referred to as delegate values. This may be done in a numeral of ways as long as the result is instinctively diplomat of the range of the base variable included in the fuzzy set[2].

Wang and Raz projected on the creation of control charts by linguistic variables. They have renewed the traditional responses into fuzzy responses. Thus fuzzy sets are assigned to each linguistic term and then using rules of fuzzy arithmetic and they are pooled for each model. The result is a single fuzzy set. A determine of centrality of the collective fuzzy set is then plotted on a Shewhart type control chart[3].

Mastrangelo and Montgomery discussed the use of uni-variate Shewhart charts in a multivariate superiority practice has indistinct the concurrent monitoring of the uniqueness in which the type 1 error and the probability of a point properly scheming in control are not identical to their advertised levels for the individual control charts[4].

Hassen Taleb and Mohamed Limam has that dissimilar actions of constructing control charts for linguistic data, based on fuzzy and probability theory, are discussed. Three sets of membership functions, with poles apart degrees of fuzziness, are planned for fuzzy approaches. An assessment stuck between fuzzy and probability approaches, based on standard Run Length and samples under control, is conducted for real time data[5].

Arthur BYeh et.al has originated an original multivariate exponentially weighted moving average (EWMA) control chart. The planned control chart, called a EWMA *V*-chart, is intended to notice small changes in the variability of correlated multivariate value quality. Throughout examples and simulations, it is established that the EWMA *V*-chart is superior to the DSD-chart in detecting little changes in practice variability. In addition, a complement of the EWMA *V*-chart for monitoring process mean, called the EWMA *M*-chart is planned. In detecting little changes in practice variability, the mixture of EWMA *M*-chart and EWMA *V*-chart is a better alternative to the blend of MEWMA control chart and DSD-chart. In addition, the EWMA *M*-chart and *V*-chart can be plotted in one single figure. As for monitoring both processes mean and process variability, the pooled MEWMA and EWMA *V*-charts supply the best control procedure[6].

Sarguna Meary, Santhakumaran and Kanmani anticipated fuzzy statistics evaluation on the alertness of corporate social responsibility. They have used fuzzy membership purpose to appraise the power factors[7].

Paolo C. Cozzucoli has anticipated to use weights that are in conditions of the geometric progression; the parameter *k* is the universal ratio of the geometric sequence. The presentation of the control chart has been evaluated using replicated data from multinomial procedure in three different hypotheses: low, high, and very high superiority level of the procedure. Properties of the *ARL* are evaluated and investigated by numerical simulations in utility of dissimilar standards of the parameter *k*. Some numerical comparisons, in terms of corresponding *ARL*, for control charts with dissimilar control limits, are planned. The control chart is more efficient in existence of very high quality level, particularly, in identifying development of the process. A fascinating methodological growth is possible considering the multivariate binomial distribution as appropriate probabilistic model to monitor the practice quality degree, since it is a more general allocation which contains the one used[8].

Shahryar Sorooshian has projected the unpredictable quality description are also better to think as feature and categorical quality description. But, control charts for monitoring attribute quality features in comparison to variable control charts have some disadvantages in arrangement which should be solved first. The second note is for monitoring excellence quality features; which because of mental examination and human judgments have some level of elusiveness and hesitation. This research proposed a new approach to quality control, a fuzzy approach for monitoring the practice when vagueness and uncertainty happen. The case study and assessment study show the anticipated approach has a better presentation and could detect abnormal shifts in the process, especially in small shifts and small sample size, faster than current related approaches[9].

Sanditya Hardaya et al. have implemented the MNP chart for multi-attribute quality control (seven correlated defect characteristics) that was alienated into two phases, that is Phase first and second Phase. In the first phase, it was obtained in-control condition, so that the control limit of MNP chart of Phase I can be used in the Phase II. In Phase II, it was found five out-of-control points which indicates there is out-of-control process.

Therefore, it is necessary to identify the defect characteristics that are being the main contributor by calculating the *Z* statistic score. From the calculation results, the defect characteristics obtained as the main contributor by selecting the largest positive *Z* score for each out-of-control sample. From the defect characteristics that have been analysed, the factors that need to be considered to keep the company's production process remain in-control conditions are as follows: i. the need of frequency optimization calculations along for bronze pouring liquid volume to be used as standards in the production process, ii. evaluation of bronze smelting process that is still accessible to unwanted elements, iii. effective and efficient machines maintenance system to prevent tear or irregularities on the machine, iv. the need of specific quality control in the sand forming to make sand molds as per the specifications and prevent such non-conformance affects the subsequent production process. The problem on certain assumptions such as the possibility of auto correlated processes, as often happens in the case of time series data, is still ignored in this study[10].

Construction of control chart using fuzzy probabilistic approach

Step-1: Identify the linguistic variables for studying the attributes in a production process and also define the appropriate membership function of each variable.

Step-2: Converting the attributes into membership values in order to assess the intermediate values lying between each variables, one can be divided in the intervals [0,1] into homogeneous or nonhomogeneous intervals with respect to the number of attributes which are proposed to study, $[0,R_1][R_1,R_2],\ldots,[R_{k-1},1]$.

Step-3: Tocalculate the fuzzy membership value

$$m_{ij} = \int_{R_{j-1}}^{R_j} \mu_{L_j}(x_j)\,dx_j \qquad i = 1,2,...,n \qquad j = 1,2,...,k$$

Where $\mu_{L_j}(x_j)$ is the membership function of the j^{th} attribute.

Step-4: Calculate the total fuzzy response quality value and the value is equal to one. That is

$$\sum_{i=1}^{n} m_{ij} = 1 \qquad j = 1, 2, ..., k .$$

Step-5: Let $L_1, L_2, ..., L_j$ are the linguistic values. The fuzzy place is denoted by F_i, and described by the association utility $\mu_{L_j}(x_j)$, where x_j is a division of the standard basic variable.

Step-6: The Control Limits are determined by membership functions. For n samples of each size $n_1, n_2, ..., n_i$ $(n_i = 1, 2, ..., n)$.

$$CL = \bar{M} = \frac{\sum_{j=1}^{k} \bar{M}_i}{n} \qquad i = 1, 2, ..., n$$

Where: $\bar{M}_i = \frac{\sum_{j=1}^{k} n_{ij} r_j}{n_i}$ is the sample mean of i^{th} sample; n_{ij} is the number of observations categorized with j^{th} linguistic term in the i^{th} sample; r_j is the fuzzy representative value of the j^{th} linguistic term and n_i is the size of the i^{th} sample.

Step-7: The control limits of central line at distances expressed on multiples of the mean deviation are given in equation.

$$\text{Membership } LCL = \text{Max}\{0, (CL - k\delta(GMF))\}$$
$$\text{Membership } LCL = \text{Min}\{1, (CL + k\delta(GMF))\}$$

Where: $k = \left(\frac{2}{3}\right)$, since the mean deviation of the Normal Distribution is $\left(\frac{2}{3}\right)\sigma \; and \; \sigma = \delta(A)$.

Step-8: Construction of control chart using Fuzzy probabilistic approach we take Fuzzy set Fi associated with the linguistic terms L_j are transformed into their respective representative values r_j. The sample mean is calculated on the average of the sample linguistic representative values r_j. For each sample i, the standard deviation SD_i is calculated as the standard deviation of the representative values of the observations in the sample.

Illustration: The data are collected from Kondalampatti, Salem Town in Tamil Nadu and classification as 20, 40, 60, 80, 100 counts. We classify the cotton sweater into five categories: Excellent, Very Good, Good, Medium and Poor. We collected 50 samples of same sizes for is shown in Table-1.

Figure-1 shows the visual representation of the cotton sweaters representative values of the plot. The entire sample means inside the control limits.

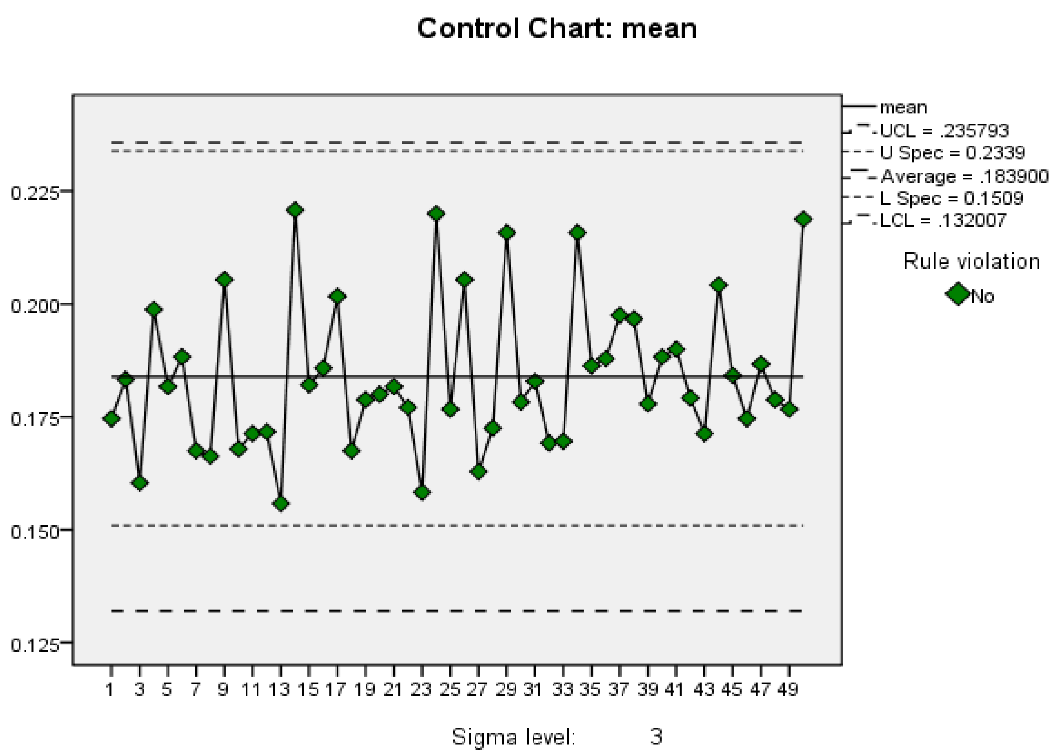

Figure-1: Fuzzy membership approach control charts.

Table-1: Attributes of Cotton sweater.

S. No	Excellent	Very Good	Good	Satisfied	Poor	Number of items
1	6	7	3	5	3	24
2	7	4	5	4	4	24
3	9	5	4	3	3	24
4	5	5	8	5	1	24
5	5	6	3	7	3	24
6	6	6	4	3	5	24
7	8	4	4	5	3	24
8	8	5	3	4	4	24
9	2	7	3	8	4	24
10	8	3	4	6	3	24
11	6	7	4	6	1	24
12	8	6	5	2	3	24
13	9	6	4	3	2	24
14	2	4	5	8	5	24
15	4	11	3	4	2	24
16	5	8	4	4	3	24
17	4	8	5	3	4	24
18	8	4	4	5	3	24
19	6	9	4	2	3	24
20	5	8	2	5	4	24
21	5	7	5	4	3	24
22	7	4	5	5	3	24
23	8	5	5	2	4	24
24	5	5	8	3	3	24
25	5	5	3	7	4	24
26	4	6	5	4	5	24
27	6	4	4	6	4	24
28	8	6	4	3	3	24

S. No	Excellent	Very Good	Good	Satisfied	Poor	Number of items
29	4	5	4	6	5	24
30	6	5	5	4	4	24
31	5	6	4	6	3	24
32	7	7	3	4	3	24
33	7	7	4	3	3	24
34	5	4	4	6	5	24
35	6	9	3	4	2	24
36	6	7	4	6	1	24
37	5	7	5	5	2	24
38	5	6	5	5	3	24
39	5	8	5	3	3	24
40	5	8	4	4	3	24
41	5	6	2	6	5	24
42	7	8	2	4	3	24
43	7	7	3	5	2	24
44	6	4	4	4	6	24
45	5	8	2	6	3	24
46	7	9	2	4	2	24
47	6	7	4	3	4	24
48	8	7	4	4	1	24
49	7	6	5	4	2	24
50	6	5	5	4	4	24

The fuzzy set be contained four attributes, namely *Fi* {L_1= Excellent: L_2= Very good, L_3 = good, L_4= Satisfied and L_5= poor, i= 1,…,n Each term L_j is associated with a fuzzy subset and described by the following membership function $\mu_{L_j}(x_j) = 24e^{-kx}, \quad if \quad x \in [0,1] \qquad i = 1, 2, ..., n.$ Where: k_1 = 0.23, k_2= 0.28, k_3= 0.16, k_4 = 0.19 and k_5 = 0.14.

For converting the attribute into membership values, in order to assess the intermediate values lieing between variables we can divide [0, 1] into five partition with heterogeneous intervals, say [0, 0.03], [0.03, 0.20], [0.20, 0.50], [0.50, 0.75] and [0.75, 1].

For calculating fuzzy response of degree of membership values are; m_{11}=0.7175, m_{12}= 3.9511, m_{13} = 6.8085, m_{14} = 4.2831 and m_{15} = 6.3927 and also obtain the total membership value is equal to 1, we have the degree of membership values are r_1, = 0.03, r_2=0.18, r_3=0.31, r_4=0.19 and r_5= 0.29 respectively. For n samples of each size n_i, i = 1, 2,…,n and n = 50, the central line at distances expressed on multiples of the mean deviation are; $CL = \bar{M} = 0.1924$, LCL = 0.1509 and UCL = 0.2339.Thus the resulting left ends, fuzzy response and right ends of 50 samples are given in Table-2.

Table-2: Membership approach control parameters.

S. No	Left end	Fuzzy response	Right end	Representative value $\overline{M_i}$	*CL*	*LCL*	*UCL*
1.	0.1267	0.1817	0.2571	0.1817	0.1924	0.1509	0.2339
2.	0.1346	0.1771	0.235	0.1771	0.1924	0.1509	0.2339
3.	0.105	0.1583	0.2308	0.1583	0.1924	0.1509	0.2339
4.	0.1525	0.22	0.2333	0.22	0.1924	0.1509	0.2339
5.	0.1558	0.1767	0.2638	0.1767	0.1924	0.1509	0.2339
6.	0.1358	0.2054	0.2463	0.2054	0.1924	0.1509	0.2339
7.	0.1504	0.1629	0.2433	0.1629	0.1924	0.1509	0.2339
8.	0.1221	0.1725	0.2504	0.1725	0.1924	0.1509	0.2339
9.	0.1638	0.2158	0.2796	0.2158	0.1924	0.1509	0.2339
10.	0.14	0.1783	0.2446	0.1783	0.1924	0.1509	0.2339
11.	0.1617	0.1829	0.2546	0.1829	0.1924	0.1509	0.2339
12.	0.1208	0.1692	0.2608	0.1692	0.1924	0.1509	0.2339
13.	0.1088	0.1696	0.2575	0.1696	0.1924	0.1509	0.2339
14.	0.1933	0.2158	0.2675	0.2158	0.1924	0.1509	0.2339
15.	0.1038	0.1863	0.2683	0.1863	0.1924	0.1509	0.2339
16.	0.1267	0.1879	0.2625	0.1879	0.1924	0.1509	0.2339
17.	0.1279	0.1975	0.2575	0.1975	0.1924	0.1509	0.2339
18.	0.1283	0.1967	0.2617	0.1967	0.1924	0.1509	0.2339
19.	0.0988	0.1779	0.2575	0.1779	0.1924	0.1509	0.2339
20.	0.1325	0.1883	0.2763	0.1883	0.1924	0.1509	0.2339
21.	0.1346	0.19	0.2742	0.19	0.1924	0.1509	0.2339
22.	0.1042	0.1792	0.2671	0.1792	0.1924	0.1509	0.2339
23.	0.1108	0.1713	0.2554	0.1713	0.1924	0.1509	0.2339
24.	0.1483	0.2042	0.2538	0.2042	0.1924	0.1509	0.2339
25.	0.1375	0.1842	0.2763	0.1842	0.1924	0.1509	0.2339

S. No	Left end	Fuzzy response	Right end	Representative value $\overline{M_i}$	CL	LCL	UCL
26.	0.0975	0.1746	0.2679	0.1746	0.1924	0.1509	0.2339
27.	0.1154	0.1867	0.2675	0.1867	0.1924	0.1509	0.2339
28.	0.1279	0.1788	0.2413	0.1788	0.1924	0.1509	0.2339
29.	0.0988	0.1767	0.2521	0.1767	0.1924	0.1509	0.2339
30.	0.1533	0.2188	0.27	0.2188	0.1924	0.1509	0.2339
31.	0.1271	0.1746	0.2558	0.1746	0.1924	0.1509	0.2339
32.	0.1346	0.1833	0.2404	0.1833	0.1924	0.1509	0.2339
33.	0.11	0.1604	0.2363	0.1604	0.1924	0.1509	0.2339
34.	0.145	0.1988	0.2379	0.1988	0.1924	0.1509	0.2339
35.	0.1504	0.1817	0.2596	0.1817	0.1924	0.1509	0.2339
36.	0.1233	0.1883	0.2508	0.1883	0.1924	0.1509	0.2339
37.	0.1333	0.1675	0.2400	0.1675	0.1924	0.1509	0.2339
38.	0.1221	0.1663	0.2450	0.1663	0.1924	0.1509	0.2339
39.	0.1688	0.2054	0.2742	0.2054	0.1924	0.1509	0.2339
40.	0.145	0.1679	0.2392	0.1679	0.1924	0.1509	0.2339
41.	0.1317	0.1713	0.2517	0.1713	0.1924	0.1509	0.2339
42.	0.1046	0.1717	0.2375	0.1717	0.1924	0.1509	0.2339
43.	0.1033	0.1558	0.2371	0.1558	0.1924	0.1509	0.2339
44.	0.1879	0.2208	0.2633	0.2208	0.1924	0.1509	0.2339
45.	0.1088	0.1821	0.2683	0.1821	0.1924	0.1509	0.2339
46.	0.1217	0.1858	0.2571	0.1858	0.1924	0.1509	0.2339
47.	0.1229	0.2017	0.2575	0.2017	0.1924	0.1509	0.2339
48.	0.1333	0.1675	0.2400	0.1675	0.1924	0.1509	0.2339
49.	0.0983	0.1788	0.2533	0.1788	0.1924	0.1509	0.2339
50.	0.1275	0.1800	0.2654	0.1800	0.1924	0.1509	0.2339
Average	**0.1303**	**0.1924**	**0.2549**	**0.1924**			

Table-3: Fuzzy probabilistic approach control parameters.

S.NO	$\overline{M_i}$	SD_i	CL	UCL	LCL
1	0.1746	0.0982	0.1924	0.2531	0.1317
2	0.1833	0.1124	0.1924	0.2531	0.1317
3	0.1604	0.1137	0.1924	0.2531	0.1317
4	0.1988	0.1360	0.1924	0.2531	0.1317
5	0.1817	0.0933	0.1924	0.2531	0.1317
6	0.1883	0.1067	0.1924	0.2531	0.1317
7	0.1675	0.1105	0.1924	0.2531	0.1317
8	0.1663	0.1093	0.1924	0.2531	0.1317
9	0.2054	0.0750	0.1924	0.2531	0.1317
10	0.1679	0.1105	0.1924	0.2531	0.1317
11	0.1713	0.0963	0.1924	0.2531	0.1317
12	0.1717	0.1141	0.1924	0.2531	0.1317
13	0.1558	0.1105	0.1924	0.2531	0.1317
14	0.2208	0.0810	0.1924	0.2531	0.1317
15	0.1821	0.0847	0.1924	0.2531	0.1317
16	0.1858	0.0949	0.1924	0.2531	0.1317
17	0.2017	0.0960	0.1924	0.2531	0.1317
18	0.1676	0.1105	0.1924	0.2531	0.1317
19	0.1588	0.1040	0.1924	0.2531	0.1317
20	0.1800	0.0921	0.1924	0.2531	0.1317
21	0.1817	0.0943	0.1924	0.2531	0.1317
22	0.1771	0.1167	0.1924	0.2531	0.1317
23	0.1583	0.1198	0.1924	0.2531	0.1317
24	0.22	0.1033	0.1924	0.2531	0.1317
25	0.1767	0.0892	0.1924	0.2531	0.1317

S.NO	$\overline{M_i}$	SD_i	CL	UCL	LCL
26	0.2054	0.1062	0.1924	0.2531	0.1317
27	0.1629	0.1065	0.1924	0.2531	0.1317
28	0.1725	0.1054	0.1924	0.2531	0.1317
29	0.2158	0.0671	0.1924	0.2531	0.1317
30	0.1783	0.1091	0.1924	0.2531	0.1317
31	0.1829	0.0944	0.1924	0.2531	0.1317
32	0.1692	0.0939	0.1924	0.2531	0.1317
33	0.1696	0.0950	0.1924	0.2531	0.1317
34	0.2158	0.0789	0.1924	0.2531	0.1317
35	0.1863	0.0876	0.1924	0.2531	0.1317
36	0.1879	0.0887	0.1924	0.2531	0.1317
37	0.1975	0.0941	0.1924	0.2531	0.1317
38	0.1967	0.0932	0.1924	0.2531	0.1317
39	0.1779	0.1009	0.1924	0.2531	0.1317
40	0.1883	0.0770	0.1924	0.2531	0.1317
41	0.19	0.0879	0.1924	0.2531	0.1317
42	0.1792	0.0921	0.1924	0.2531	0.1317
43	0.1713	0.1043	0.1924	0.2531	0.1317
44	0.2042	0.1045	0.1924	0.2531	0.1317
45	0.1842	0.0740	0.1924	0.2531	0.1317
46	0.1746	0.0890	0.1924	0.2531	0.1317
47	0.1867	0.0876	0.1924	0.2531	0.1317
48	0.1788	0.1101	0.1924	0.2531	0.1317
49	0.1767	0.1054	0.1924	0.2531	0.1317
50	0.2188	0.0807	0.1924	0.2531	0.1317
Average		**0.0981**			

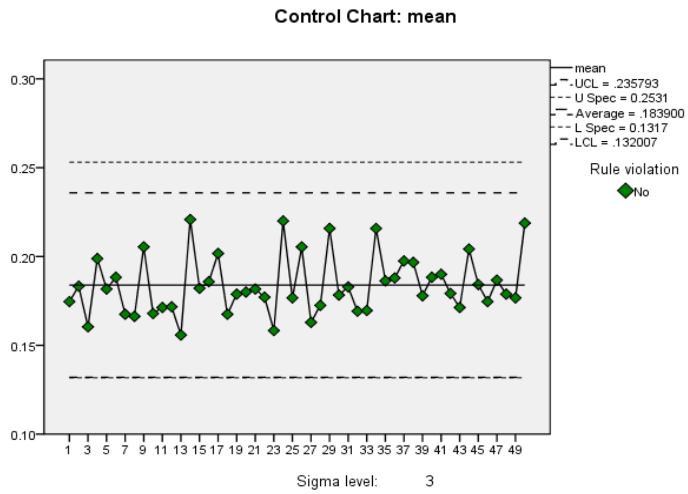

Figure-2: Fuzzy probabilistic approach control charts

One can see from Figure-2, all the samples are indicates in control signal at Fuzzy probabilistic approach control chart. With the comparison between the two approaches, both control charts detect same decision for the cotton sweater color and this average run length is given in Table-4.

Conclusion

In this present study of membership approach and fuzzy probabilistic approach control charts using variables have more flexible and appropriate than classical control chart approaches. The performance of the fuzzy probabilistic and membership approach control charts depend on assessing the degree of human feeling when the membership functions are reflecting people's complete and definite thought on the linguistic variables.

Table-4: Average run length.

Number of items	k	β	$ARL=\dfrac{1}{1-\beta}$
14	0.25	0.9803	50.7614
	0.50	0.8708	7.7399
	0.75	0.5759	2.3579
	1.0	0.2297	1.2982
	1.25	0.0446	1.0467
	1.50	0.0045	1.0045
17	0.25	0.9750	40.0000
	0.50	0.8264	5.7604
	0.75	0.4602	1.8525
	1.0	0.1314	1.1513
	1.25	0.0158	1.0161
	1.50	0.0007	1.0007
19	0.25	0.9719	35.5872
	0.50	0.7939	4.8520
	0.75	0.3936	1.6491
	1.0	0.0869	1.0952
	1.25	0.0073	1.0073
	1.50	0.0002	1.0002
23	0.25	0.9641	25.8552
	0.50	0.7257	3.6456
	0.75	0.2743	1.3780
	1.0	0.0359	1.0372
	1.25	0.0014	1.0014
	1.50	0.0000	1.0000

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