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# RESEARCH ON RESOLUTION OF ORBIT BASED ON CLUSTERING ANALYSIS AND BP NETURAL NETWORK IN SSRF*

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*Abstract*

Keeping the beam current's normal motion is an important mission for Shanghai Synchrotron Radiation Facility (SSRF). So the Orbit (rms)x/y is an main parameter for SSRF's running. However, the orbital resolution has been constrained by the accuracy of acquired data. To eliminate BPM's failure causing the inaccurate orbital resolution, the work based on clustering analysis and BP neural network to removed the abnormal BPM and recalculate the resolution of orbit. Experiment data came from the machine research. The analysis results showed that the rms value of orbit was 100.75 μm (x direction) and 14.9 μm (y direction) using all BPM's data but the recalculate value was 98.03 μm (x direction) and 2.6 μm (y direction) when eliminated the data of faulty BPM. The analysis result indicated that the method can optimize the resolution of orbit and next work is further to evaluate the orbital resolution with more operation data.

## INTRODUCTION

The storage ring in SSRF is equipped with different machine parts located at 20 cells of the storage ring to monitor the beam dynamics [1]. Due to the accidental error of machine parts and the collimation error of each magnet, particles usually deviate from ideal orbit to form orbit and it can result in machine performance degradation or even failure. Good orbit is the foundation of accelerator operation, and orbit correction is the most basic of current accelerator beam adjustment. And it is also one of the most widely studied fields at present. As a beam monitoring system, the BPMs at the beam lines after the insertion devices (ID) or the bending magnets are also of great importance, because they also serve as the orbit feedback system to ensure stability of the electron Beams [2]. Meanwhile, the BPM confidence levels included in the feedback system can be used to estimate stability of the beam dynamics. The BPMs can monitor the stability of beam Orbit. Therefore, an abnormal BPM should be found and treated to avoid the deviation calculation for beam orbit.

A typical BPM system consists of the probe (button-type or stripline-type), electronics (Libra Electronics/ Brilliance in SSRF) and transferring component (cables and such). Ever since the SSRF commissioning in 2009, the BPM have occurred all kinds of malfunction. They were permanently damage of individual probe or corre-sponding cable, misaligned (position/angle) probes, high-frequency vibrations, electronics noise, and others. These faults mean totally useless of the signals from the BPM, which should be ignored until its replacement or repair. Hence, it is essential to find an effective method to detect the faulty BPM and revise the beam orbit.

With development in machine learning methods, a series of powerful analysis approaches make it possible for detecting beam position monitor's stability. Cluster analysis is one of machine learning methods. It is aimed at classifying elements into categories on the basis of their similarity [3]. Its applications range from astronomy to bioinformatics, bibliometric, and pattern recognition. Clustering by fast search and find of density peaks is an approach based on the idea that cluster centres are characterized by a higher density than their neighbours and by a relatively large distance from points with higher densities [4]. This idea forms the basis of a clustering procedure in which the number of clusters arises intuitively, outliers are automatically spotted and excluded from the analysis, and clusters are recognized regardless of their shape and of the dimensionality of the space in which they are embedded. In addition to, it is able to detect non-spherical clusters and to automatically find the correct number of clusters.

Based on the advantage of clustering by fast search and find of density peaks, this study located and removed the faulty BPM at SSRF. Through we removed the faulty BPMs, considering the beam integrity, the research work used the BP netural network to fit the beam position in all BPM's data (the removed BPMs's collected data were replaced the fitted data ).

## EXPERIMENTAL DATA AND ANALYSIS METHOD

### *Experimental Data and Acquisition System*

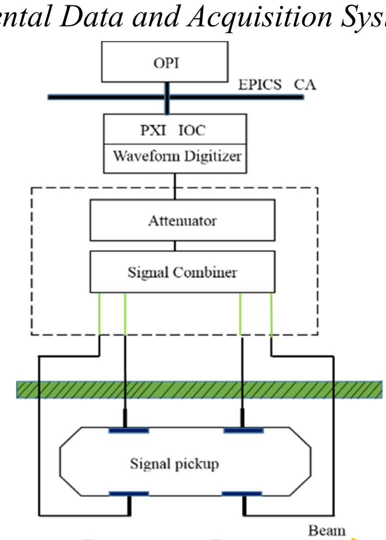


Figure 1: Acquisition system layout.

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In this study, the experimental data were collected from the BPM turn-by-turn (TBT) data. The acquisition system was shown in the Fig.1. By analysing the raw data, the study work extracted the data of of X and Y direction to research the resolution of beam orbit.

### *Multi-Dimensional Clustering Analysis Model and BP Netural Work*

In this work, a multi-dimensional clustering analysis model was established. The created model based an assumption that cluster centres should be surrounded by neighbour points with lower local density and that they are at a relatively large distance from any points with a higher local density. For each data point i, it was computed two quantities: its local density ρi and its distance δi from points of higher density. Both these quantities depend only on the distances dij between data points, which are assumed to satisfy the triangular inequality. The local density ρi of data point i is defined as

$$\rho_i = \sum_j \chi(d_{ij} - d_c) \tag{1}$$

where $\chi$ (x) =1 if x < 0 and $\chi$ (x)=0 otherwise, and $d_c$ is a cutoff distance. Basically, $\rho_i$ is equal to the number of points that are closer than $d_c$ to point *i*. The algorithm is sensitive only to the relative magnitude of $\rho_i$ in different points, implying that, for large data sets, the results of the analysis are robust with respect to the choice of $d_c$. In this paper, the $d_c$ is 0.02. On the other hand, $\delta_i$ is measured by computing the minimum distance between the point *i* and any other point with higher density:

$$\delta_i = \min_{j:\rho_j > \rho_i} (d_{ij}) \tag{2}$$

For the point with highest density, we conventionally take $\delta_i = \max_j (d_{ij})$. Note that $\delta_i$ is much larger than the typical nearest neighbour distance only for points that are local or global maxima in the density. Thus, cluster centres are recognized as points for which the value of δi is anomalously large. Generally, the value of δi and ρi represent whether the point is cluster centre, the typical characteristic of cluster centre is the value of δi and ρi are larger. Decision graph could depict the value of $\delta_i$ and ρi and show which points are cluster centre. By the multi-dimensional clustering analysis model, the study removed the faulty BPMs. Meanwhile, the work used the BP netural networks to fit the beam position in all BPM's data.

## RESULTS AND DISCUSSION

### *To Verify the Effectiveness of Multi-Dimensional Clustering Analysis Model*

The BPM's data has been acquired from the average signal of 140 ID* 3000 turns. The scatter diagram was shown in the Fig. 2. It could see that most of BPM are in together, means that BPMs acquisition signals are normal. The rest scattered were around the big group but the 75# and 68# BPM are away from the big group. Theoretically, the farther away the normalization value 1 for the transverse oscillation, the more easily anomaly for those BPMs. 75# and 68# BPMs may be the malfunction of BPMs, because they are far away the big group.

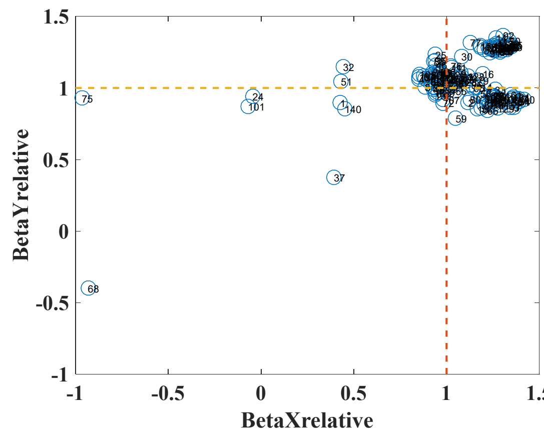


Figure 2: Scatter diagram based on β oscillation of X and Y direction.

The study use multi-dimensional clustering analysis model to analysis the beam running data to judge the working performance of all BPMs. Theoretically, when beam position monitors are isolated and away from group, they are probability faulty beam position monitors which faulty BPM corresponds to the smaller ρ and the larger δ. Base on the nature idea, the work calculated the decision graph that could show which BPM is the cluster centre and which is isolated. On the math, cluster center should be those surrounded by other point with lower local density ρi and they are at a relatively large distance from any points with a higher local density. The decision graph was shown in Fig. 3. The 68# and 75# has a relatively high δ and relatively low ρ, it can be considered as cluster which was composed of a single point (isolated), namely, meaning a faulty BPM. From the analysis results, in Fig. 4, most of BPMs are gather together; through it included three small group.

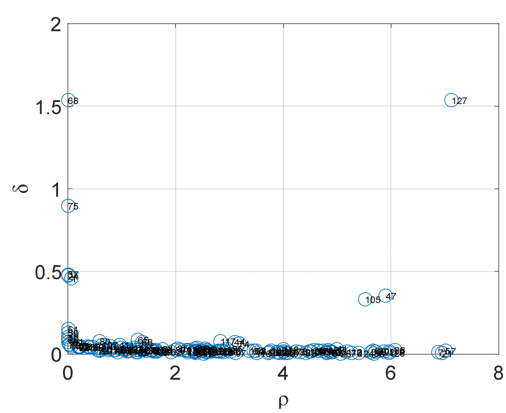


Figure 3: Decision graph.

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Through the above analysis, the multi-dimensional clustering analysis model could classify all BPMs with the input variable are β oscillation of X and Y directions. The abnormal and performs worse BPMs could be separated. The other BPMs were be classified into three small group.

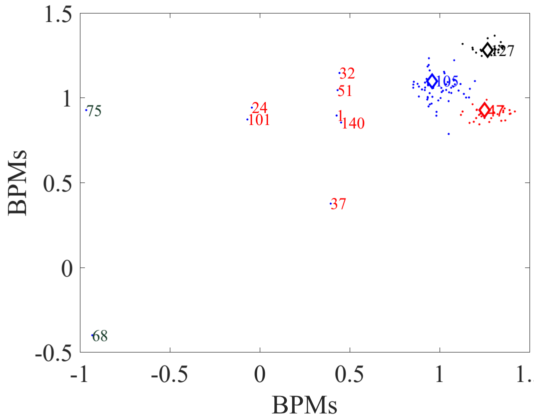


Figure 4: Clustering analysis results.

### *To Removed the Faulty BPMs and Refit the Beam Orbit*

Based on the acquired data, the rms value of orbit is 100.75 μm (x direction) and 14.9 μm (y direction) using all BPM's data. Through the clustering analysis, the 75# and 68# were broken and the 24#, 32#, 1#,37#, 51# and 101# BPM were worse performance BPMs. So we remove these BPMs to recalculate the beam orbit. The BP netural network [5] were be used to fit the removed BPMs.

The result showed that the rms value of orbit is 98.03 μm (x direction) and 2.6 μm (y direction) in the Fig. 5 and Fig. 6. And the R value are 0.99421 and 0.9681, respectively. The analysis result indicated that the method can optimize the resolution of beam orbit and next work is further to evaluate the orbital resolution with more operation data.

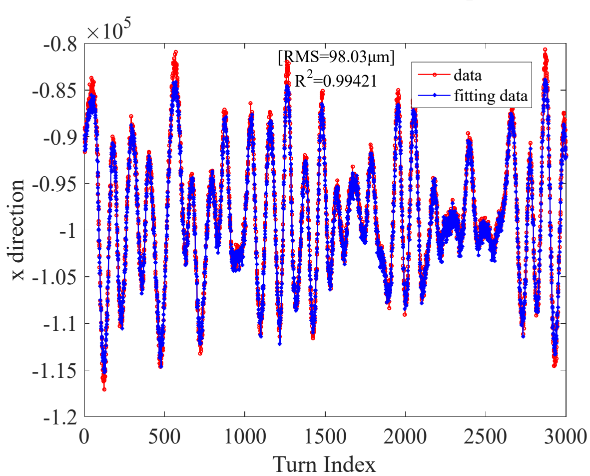


Figure 5: The beam orbit of X direction.

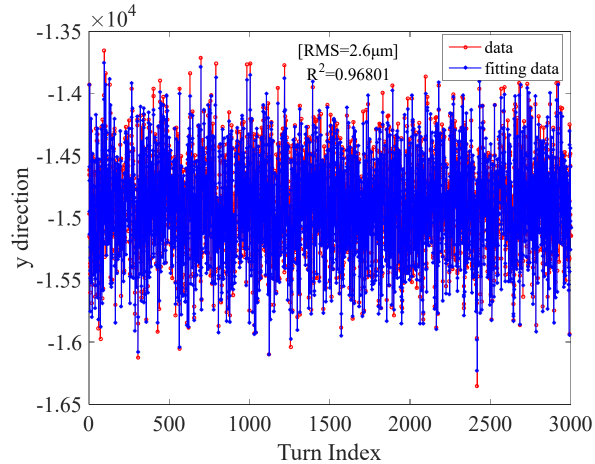


Figure 6: The beam orbit of Y direction.

## CONCLUSION

As a user facility, beam stability is of utmost importance and high priority. High beam stability is one of the most fundamental processes used for beam control in accelerators. Improving its orbit stability can optimize the performance of the accelerator and promote the experimental output in machine research time. This work made use of the characteristics of many channels and large amount of data for the beam measuring system, develop a new method based on clustering analysis and BP netural network, explore the feasibility of the application in keeping the beam orbit stability.

The experimental results demonstrate that the proposed cluster analysis method could capture the faulty BPMs. Especially, the decision graph could be find more key information about BPMs. Meanwhile, the analysis results demonstrate the rms value of orbit is 98.03 μm (x direction) and 2.6 μm (y direction). The real beam orbit were corrected. But the validity needs more numbers to back it up.

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