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Mixed Integer Programming-Based One-Class Classification Method for Process Monitoring

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Abstract : One-class classification plays an important role in detecting outlier and abnormality from normal observations. In the previous research, several attempts were made to extend the scope of application of the one-class classification techniques to statistical process control problems. For most previous approaches, such as support vector data description (SVDD) control chart, the design of the control limits is commonly based on the assumption that the proportion of abnormal observations is approximately equal to an expected Type I error rate in Phase I process. Because of the limitation of the one-class classification techniques based on convex optimization, we cannot make the proportion of abnormal observations exactly equal to expected Type I error rate: controlling Type I error rate requires to optimize constraints with integer decision variables, but convex optimization cannot satisfy the requirement. This limitation would be undesirable in theoretical and practical perspective to construct effective control charts. In this work, to address the limitation of previous approaches, we propose the one-class classification algorithm based on the mixed integer programming technique, which can solve problems formulated with continuous and integer decision variables. The proposed method minimizes the radius of a spherically shaped boundary subject to the number of normal data to be equal to a constant value specified by users. By modifying this constant value, users can exactly control the proportion of normal data described by the spherically shaped boundary. Thus, the proportion of abnormal observations can be made theoretically equal to an expected Type I error rate in Phase I process. Moreover, analogous to SVDD, the boundary can be made to describe complex structures by using some kernel functions. New multivariate control chart applying the effectiveness of the algorithm is proposed. This chart uses a monitoring statistic to characterize the degree of being an abnormal point as obtained through the proposed one-class classification. The control limit of the proposed chart is established by the radius of the boundary. The usefulness of the proposed method was demonstrated through experiments with simulated and real process data from a thin film transistor-liquid crystal display.

Keywords : control chart, mixed integer programming, one-class classification, support vector data description
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