Transform Domain Morphological Filters

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Summary

In this thesis, we have studied the concept of mathematical morphology and morphological operators to devise new methods to recognise and reassemble paths and patterns through point-clouds. These are methods which act on local or global shape-related properties of the components of an n-dimensional image. These components may be accepted, modified or discarded based on their morphological properties. These methods may fail when the components in an image overlap; a solution to this was introduced by the concept of attribute-space connectivity and filtering. In this concept, the input image is transformed in to a higher dimensional space (transform domain) by a transform operator which assigns one or more attributes to each pixel. Attribute-filters could be applied to the newly obtained data. After application of filters, the data is transformed to its original domain using the corresponding inverse transform operator.

These methods have been applied to data generated by a simulator for a sub-atomic interaction detection system (PANDA). Specifically, the data from the tracking detector system (STT) have been used to reconstruct paths of charged particles passing through magnetic field. Traditionally, the tracking task was done using various methods (Hough transform, Conformal mapping, etc.) to reconstruct particle tracks together with a number of physics properties. These methods are capable of producing results with high precision, but none of them is directly suited for online data processing and reduction where, typically, limited compute power is available because of conditions such as heat transportation, space limitations or other limitations imposed by embedded hardware.

We showed that application of morphological connected filters in transform space is a candidate solution to this challenging problem. It was shown that by exclusively using the detectors' local data and geometry, a rough estimate of the paths in 3D could be made; those estimated paths could be used to decide either to keep or discard a certain track. Because of the simplicity and intuitiveness of the introduced method, it could be utilised on rather simple hardware or maybe even on the readout system of the STT sub-system of the PANDA detector. Although, the introduced algorithm was not optimised for memory and computation-time

efficiency, its proof of concept implementation showed that it was capable of solving a part of the online tracking challenge and could produce results within acceptable error margins.

The geometry of many complex detection systems and sensor networks could be modelled by generic graphs. Each sensor is represented by a node and the connections between the nodes are defined using the graph edges. The local properties of each sensor is stored in the internal structure of the corresponding node. When a measurement is performed, the produced data could be considered as a pattern in n-dimensional space. Considering this concept, it is possible to process the outcome of many multi-sensor systems using the mathematical morphology and (transform-domain) morphological connected filters. The detection system itself is represented as a graph and the readouts of a recorded event as a pattern. To facilitate this processing scheme, a graph based formalism was defined for time and memory efficient application of attribute-space connected filtering.

Hierarchical structures such as Max-Tree were introduced and studied to process grey-scale images. The basic idea is to create connected regions of the same intensity, the so called flat regions, by application of a series of thresholds on the input image and to structure these regions in a hierarchy one on top of the other. Various attributes could be calculated while the tree is being built or afterwards for the tree nodes which could be used by morphological (connected) filters to perform tasks such as denoising, segmentation or data compression. This hierarchical structuring could also be applied to data in transform domain. By application of transform function pairs (transform F and its inverse F^{-1}) the input data can be transformed in to a different domain where attributes could be determined for the data in its new domain. After application of morphological (connected) filters, the results are transformed by F^{-1} to the original domain of input. As a demonstration of this concept, it was applied to images transformed to wavelet domain. To compute the transforms and their inverses, traditional wavelet transform-functions were used. A number of morphological attributes have been calculated on data in wavelet domain and used to filter the input to achieve image compression.