Integral Images and Applications to Image Processing

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Abstract

One of the many tools that are extremely useful in image processing is the idea of integral images — an algorithm based on dynamic programming — that is used to efficiently sum the intensities of all pixels in a rectangular window. This operation finds heavy usage in the area of pattern matching for object detection (the well-known Viola-Jones object detection framework was the first to use it for this purpose). In image processing, the speed of any algorithm is of high importance because the size of the input is extremely large (consider $\sim 1024 \times 768$ pixels). The problem is as follows: in order to perform detection, we use filters that add and subtract pixels in various rectangular windows. These windows need to be translated over the entire image, and the operation repeated in each configuration. Consider a $k \times k$ window in an $n \times n$ image ($k \ll n$). A naive implementation would involve iterating through nearly n^2 rectangles, summing k^2 pixels each time. Integral images reduces this to a one-time $\mathcal{O}(n^2)$ cost, following which the task of summing pixels within any window is a constant time operation. The complexity is therefore linear in the number of pixels.