Regions of Interest in the Context of ImgLib2

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April 29, 2012

Abstract

This document collects some naive thoughts about what we consider a region of interest (ROI). Our ideas are biased towards what we can imagine to use it for and express it in the context of ImgLib2.

1 Regions of Interest

A region of interest (ROI) is a function \( f : \mathbb{R}^n \rightarrow [0, 1] \) that assigns a real precision interest value ranging from 0 to 1 to each coordinate in an \( n \)-dimensional Euclidean space. Such a function can be interpreted as a probability map. The ‘negation’ of a ROI \( f(x) \) is defined as \( \neg f(x) = 1 - f(x) \). In natural terms, a coordinate is ‘inside’ of the ROI by an amount of \( f(x) \) and ‘outside’ of the ROI by an amount of \( \neg f(x) \). The intersection of two ROIs \( f(x) \) and \( g(x) \) can be be computed using pairwise multiplication of interest values. Using these basic operations

\[
\neg : \quad (\neg f)(x) = 1 - f(x) \quad (1) \\
\cap : \quad (f \cap g)(x) = f(x) \cdot g(x) \quad (2)
\]

other set operations on ROIs can be defined.

\[
\cup : \quad f \cup g = \neg (\neg f \cap \neg g) \quad (3) \\
\setminus : \quad f \setminus g = f \cap \neg g \quad (4)
\]

Additional operations can be defined that have no straightforward interpretation as probabilities

\[
\text{max} : \quad \max(f, g)(x) = f(x) \text{ if } f(x) > g(x), \text{ otherwise} \quad (5) \\
\text{min} : \quad \min(f, g)(x) = f(x) \text{ if } f(x) < g(x), \text{ otherwise} \quad (6) \\
\oplus : \quad (f \oplus g)(x) = \min(1, f(x) + g(x)) \quad (7) \\
\ominus : \quad (f \ominus g)(x) = \max(0, f(x) - g(x)) \quad (8)
\]

In ImgLib2, a generic ROI would implement the \texttt{RealRandomAccessible} interface with a specialized \texttt{RealType} that implements \texttt{add} and \texttt{sub} as described above preserving the \( [0, 1] \) range and an in-place \texttt{invert} method as described above.

Various forms of ROIs exist. Specializations constrain either the domain or the co-domain of the general ROI. Following a few examples:
In ImgLib2, a generic discrete ROI would implement the \texttt{RandomAccessible} interface. If the domain is limited (as it is in a digital image) it would implement the \texttt{RandomAccessibleInterval} and optionally the \texttt{IterableInterval} interfaces. Iteration can be achieved through \texttt{Views.iterable}.

In a mask, a coordinate is either ‘inside’ or ‘outside’ of the ROI. Two masks can be combined using boolean operations

\begin{align*}
\neg: & \quad (\neg f)(x) = \overline{f(x)} \\
\cap: & \quad (f \cap g)(x) = f(x) \land g(x) \\
\cup: & \quad (f \cup g)(x) = f(x) \lor g(x) \\
\setminus: & \quad (f \setminus g)(x) = f(x) \land \overline{g(x)}
\end{align*}

which, using \(\perp = 0\) and \(\top = 1\), is consistent with the above definitions.

A ROI may only specify its non-zero coordinate value pairs explicitly. All other coordinates are then implicitly considered zero that is ‘outside’ of the ROI. Per definition, a discrete ROI may be transferred to real space by assigning all real coordinates in the rounded environment of a discrete coordinate to the value of the discrete coordinate. This is equivalent to nearest neighbor interpolation. Accordingly, this transfer can be generalized to defining an \(n\)-dimensional region of interest in real space as the set of the Voronoi regions of explicitly specified coordinate value pairs.

## 2 The current status in ImgLib2

Lee Kamentsky has created the package \texttt{net.imglib2.roi} containing several concrete classes that all implement a generic \texttt{RegionOfInterest} interface that implements a \texttt{RealRandomAccessibleInterval} with a \texttt{BitType}. In terms of the above definitions that corresponds to a bounded mask.