Regions of Interest in the Context of ImgLib2

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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 $f : \mathbb{R}^n \to [0, 1]$ 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

$$\neg : \quad (\neg f)(x) = 1 - f(x) \tag{1}$$
$$\cap : \quad (f \cap g)(x) = f(x) \cdot g(x) \tag{2}$$

other set operations on ROIs can be defined.

$$\cup : \quad f \cup g = \neg(\neg f \cap \neg g) \tag{3}$$
$$\setminus : \quad f \setminus g = f \cap \neg g \tag{4}$$

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

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

In ImgLib2, a generic ROI would implement the `RealRandomAccessible` interface with a specialized `RealType` that implements `add` and `sub` as described above preserving the $[0, 1]$ range and an in-place `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:

$$
\begin{aligned}
\text{Discrete ROI} \qquad & f: \mathbb{Z}^n \to [0,1] & (9)\\
\text{Mask} \qquad & f: \mathbb{R}^n \to \{0,1\} & (10)\\
\text{Discrete Mask} \qquad & f: \mathbb{Z}^n \to \{0,1\} & (11)\\
\text{Polygon Mask} \qquad & f: \mathbb{R}^2 \to \{0,1\} & (12)
\end{aligned}
$$

In ImgLib2, a generic discrete ROI would implement the `RandomAccessible` interface. If the domain is limited (as it is in a digital image) it would implement the `RandomAccessibleInterval` and optionally the `IterableInterval` interfaces. Iteration can be achieved through `Views.iterable`.

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

$$
\begin{aligned}
\neg: \qquad & (\neg f)(x) = \overline{f(x)} & (13)\\
\cap: \qquad & (f \cap g)(x) = f(x) \wedge g(x) & (14)\\
\cup: \qquad & (f \cup g)(x) = f(x) \vee g(x) & (15)\\
\setminus: \qquad & (f \setminus g)(x) = f(x) \wedge \overline{g(x)} & (16)
\end{aligned}
$$

which, using $\bot = 0$ 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 `net.imglib2.roi` containing several concrete classes that all implement a generic `RegionOfInterest` interface that implements a `RealRandomAccessibleInterval` with a `BitType`. In terms of the above definitions that corresponds to a bounded mask.