

Interval–state cellular automata and their applications to image segmentation

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Introduction

In previous studies [1, 2] we have shown how multi–state Cellular Automata (CA) can be used for image segmentation. Our main aim is to segment features of semantic interest out of simple greyscale images, with a long–term goal of applying CA to the segmentation of medical data. We do this by imagining each pixel as an agent having to decide its membership to a particular geographic region, and changing its own value according to the values of its surrounding neighbours.

Comparisons of intervals

Our CA update rule relies heavily on comparisons of pixel values such as `if x < y then ...`. When `x` and `y` are intervals, the comparison gets tricky because of potential interval overlap.

Whilst for scalars there are only three elementary comparison operators (`<`, `=` and `>`), there are as many as 18 well–defined relative

Interval $M = [\underline{M}, \overline{M}]$ which belongs to the current pixel in one iteration is adjusted according to the update rule in the following iteration:

- C_S is the interval closest in value to M where $C_S <_{[] M$
- C_G is the interval closest in value to M where $C_G >_{[] M$
- F_S is the interval furthest in value to M where $F_S <_{[] M$
- F_G is the interval furthest in value to M where $F_G >_{[] M$

In order to measure how far in value two intervals $\mathbf{x} = [\underline{x}, \overline{x}]$, $\mathbf{y} = [\underline{y}, \overline{y}]$ are, we use the Hausdorff distance $d_H(\mathbf{x}, \mathbf{y}) = \max(|\underline{x} - \underline{y}|, |\overline{x} - \overline{y}|)$. If, for example, we denote $dC = d_H(C, M)$, then we can define update rules for the interval associated with each pixel. One of the simplest update rules for the close intervals can be defined thus:

if $dC_S < dC_G$ **then**
 $\underline{M} = \min(\overline{C_S}, \underline{M})$
 $\overline{M} = \max(\underline{C_S}, \overline{M})$
else
 $\underline{M} = \min(\underline{C_G}, \overline{M})$
 $\overline{M} = \max(\overline{C_G}, \underline{M})$

Any such rule constrains the greyscale range for each pixel to a set of discrete integer values. In the generic case, there would be no such overall requirement: it is easy to envisage a model whereby the greyscale range can become a true range over a real continuum. Indeed, one such model features within our future projects.

Results

We have obtained promising results using the above rule on synthetic images with an appropriate amount of noise, as well as on conventional real-world images. Initial experiments were carried out on a dozen images from the Berkeley Segmentation Dataset [4], which usefully provides the corresponding ground-truth human segmentations.

Figure 2 illustrates in left columns the raw data, and in right columns the corresponding machine segmentation generated after 30 iterations of our interval-based algorithm. The interval pixels obtained

after the final iteration were thresholded with a method similar to Otsu’s [5], where greyscale values are split according to the peaks in the image histogram, thus generating semantically interesting regions in the image. The methods can be improved further by using conventional pre- and post-processing steps. We have intentionally applied the CA in the absence of any conventional filtering methods so as to highlight the viability of the CA-based segmentations.



Figure 2: Raw data and corresponding machine segmentations obtained after 30 iterations, with thresholding.

References

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