Using Water to Guide Image Feature Extraction

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ANALOGIES

A new way of dealing with problems in the area of computer vision is through the use of analogy to physical phenomena. Ideas such as heat, force and water have been used to extract features and information from an image. Analogies are more intuitive than some arbitrary procedure so they can be controlled and understood far more easily.

Water is an excellent phenomena to use in an analogy because everyone has at least a basic understanding of how it works, and the more complex ideas are intuitive. The simplest concept is that of flow and flooding; where water moves from one place to another. Adhesion is tendency of water to stick to the vessel that it travelling in, surface tension is the tendency of the surface of the water to retain the smallest possible area and viscosity is the resistance to flow caused by the attraction of water particles themselves. Two examples of its use are watersheds[1] and water flow.

FORCE FIELD TRANSFORM

The force field transform [2] is an sensational new paradigm used in the water flow method that creates a force field from an image. In the transform each pixel of an image generates a force field dependant on the intensity of the pixel (analogous to a gravitational or magnetic field in physics) which exerts a force on every other pixel, subject to the inverse square law. In the left figure the light pixels have a large force present on them, as well as a direction that this force acts in.

FEATURE EXTRACTION

Image feature extraction is the process of taking a complex image and extracting parts of it that are useful for processing. A very simple example is edge detection which is commonly performed by taking the gradient of an image. The main focus of this work has been on that of image segmentation. Segmentation is the process of dividing an image into parts and there are two common methods to do this; active contours and region growing. Active contours (also called snakes) are a curve (normally a loop) that closes (or expands) around an object to fully encase it. Region growing techniques involve taking a seed and expanding to neighbouring pixels if there is some homogeneity between the pixels (intensity, texture or edges for example).

WATER FLOW

The Water Flow method [3] is a new technique combining elements of region growing and active contours with a water analogy. From a source we use use flow equations to simulate the flow of water over an image taking into account image features. At each iteration we examine the contours (the boundaries between water and non-water) and if the flow velocity and energy are positive in a direction then the water flows to the adjacent pixel.

Flow velocity is described by a driving force which. The driving force is found by performing the force field transform on a specially constructed image, where the internal water has a weak repulsive force on it to push the flow outwards and the edges have a strong attractive force. This attractive force enables the water to 'stick' to edges and emulates adhesion. The overall driving force is then always pushing the water away from the contour and towards any edges. The resistance is something that slows the velocity down and replaces forces like viscosity. By choosing what resistance represents the features extracted can be changed

The next stage examines the energy of the water taking into account more force. The potential force performs some of the functions of surface tension in enabling flow to not overflow edges. The statistical force works to ensure homogeneity in the pixels outside the contour and the flood pixels. If the energy is positive the flow completes and it continues until the contour is static.

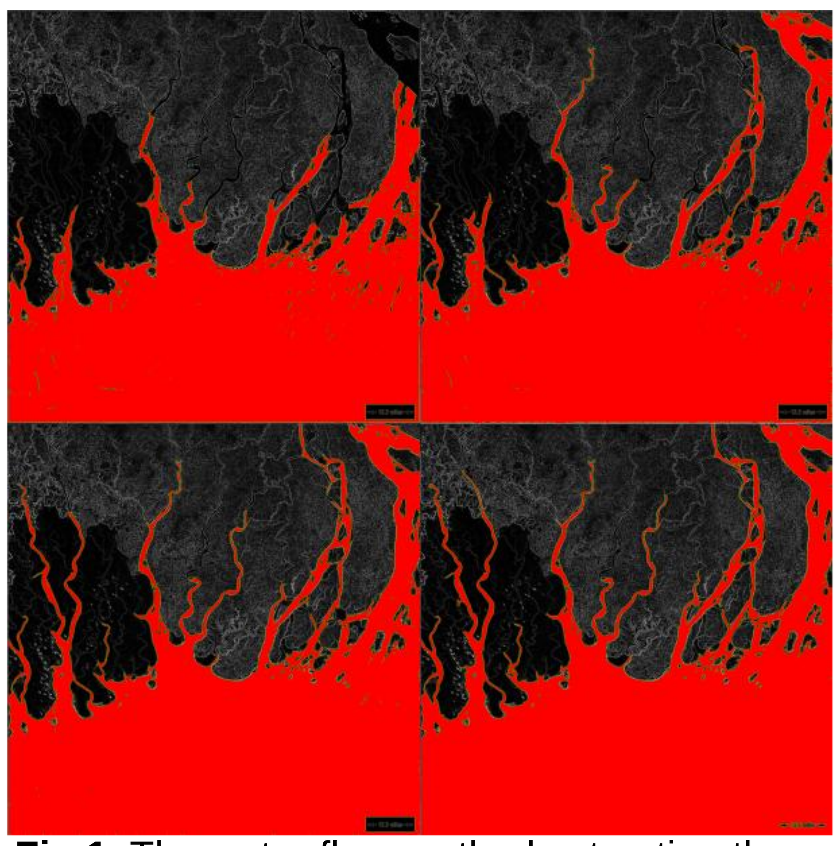

Fig 1. The water flow method extracting the Ganges River delta with resistance parameter={1,0.8,0.6,0.4}

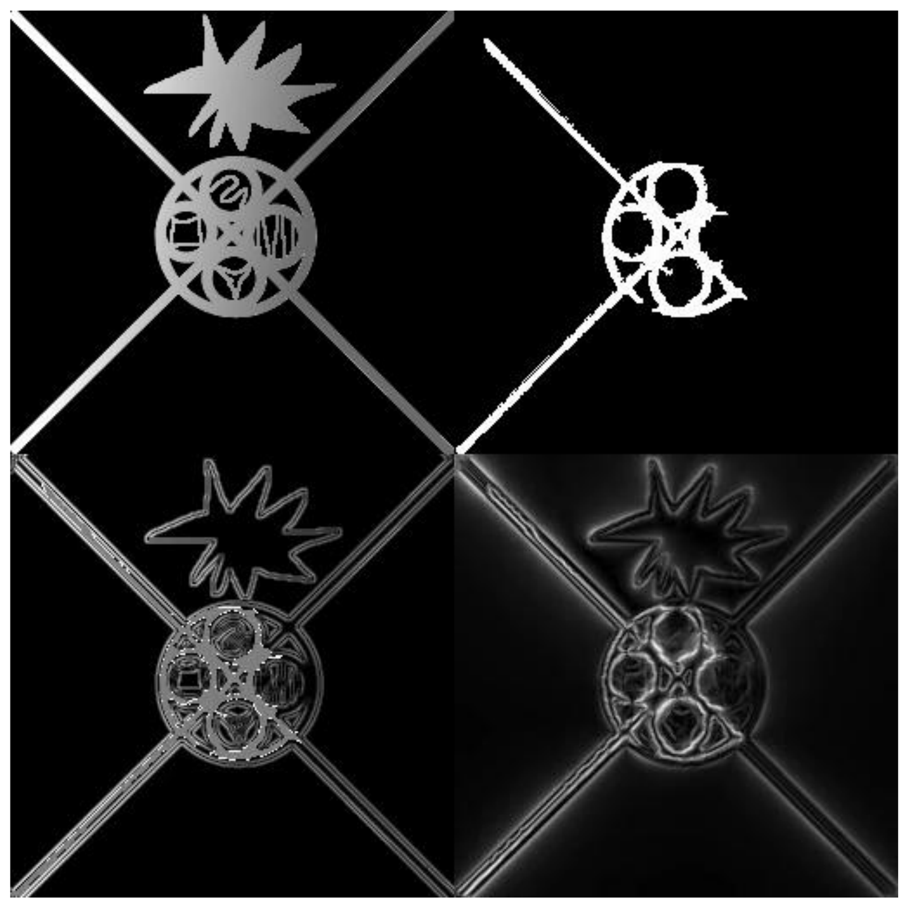

Fig 2. The effect of higher viscosity on flow

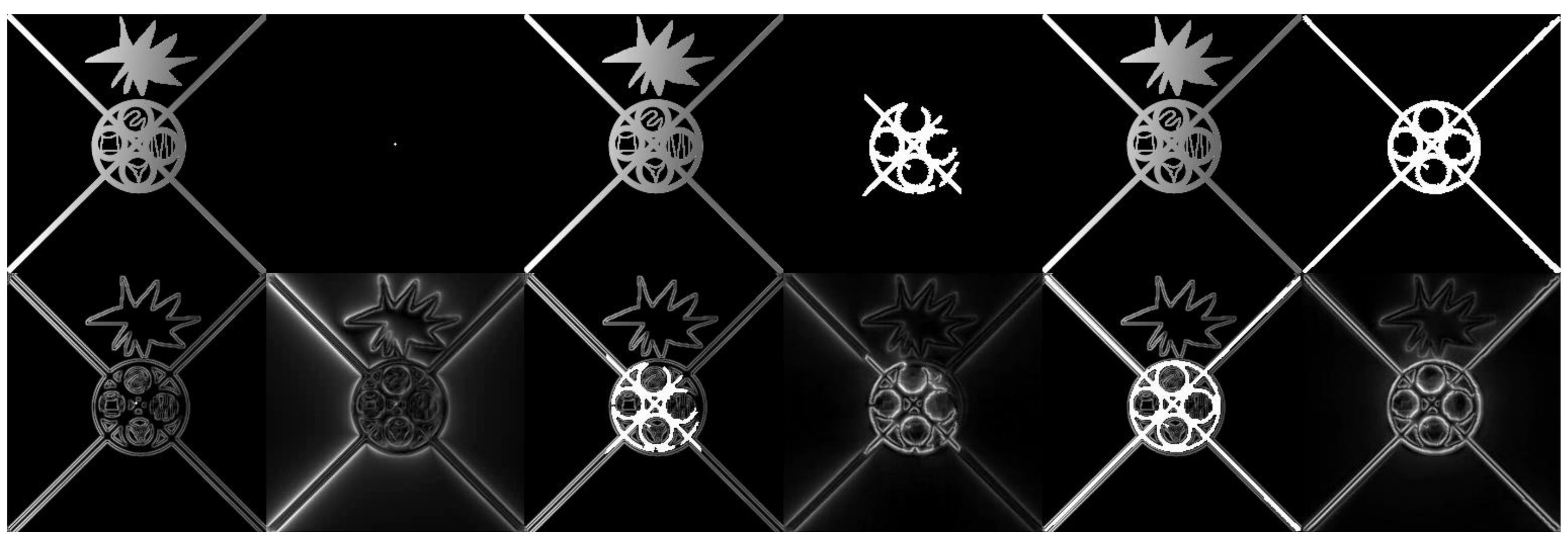

Fig 3. The state of the water flow method at 0,50 and 200 iterations

EXPERIMENTS & RESULTS

The water flow method was implemented in Python and C and tested. Both a simpler version and the one described above were tested, with the simpler one being significantly quicker, but the force field version having behaviour that had more similarity than water. In Figure 1 the results of the the method on an image of the Ganges River delta can be seen. Each image represents the point where the contour had mostly stopped advancing at each resistance level; with less resistance the flow overcomes some obstacles and floods them.

In Figure 3 the state of the algorithm can be seen. At 0, 50 and 200 iterations. In each of the pictures, the top left represents the original image, the top right is the water matrix (the flooded areas), the bottom left is the input to the force field transform and the bottom right is the resultant force field. Over time it can be seen how the relative strength of the edges is overwhelmed by the strength of the repulsion of the water.

An attempt was made to include an explicit surface tension force into the energy equation so as to reduce overall curvature, and not just to bridge gaps. Unfortunately this force had two effects: none, or stopping all flow entirely. Adding viscosity to the algorithm was also attempted, with more success. Vicosity worked by reducing the repulsive effect of the water. In Figure 2 it can be seen that the viscosity has reduced the energy of the water flow enough that the statistical force can prevent it passing into areas with less intensity to the rest of the water.

CONCLUSIONS

This project has examined the use of water analogies in feature extraction and seen how they have many strengths such as their intuitive nature and easily controllable parameters but have weaknesses such as sometimes being slow. The water flow method has many new areas into which it could be expanded; pressure and temperature in addition to the ones looked at in this work. The use of analogies in computer vision is only just beginning and there are many completely different physical phenomena that can be converted into some useful feature extraction technique.

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