Information Fusion of Multi-Sensor Images

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INTRODUCTION

The human perception to the outside world is the results of action among brain and many organs. For example, the intelligent robots that people currently investigate can have many sensors for sense of vision, sense of hearing, sense of taste, sense of smell, sense of touch, sense of pain, sense of heat, sense of force, sense of slide, sense of approach (Luo, 2002). All these sensors provide different profile information of scene in same environment. To use suitable techniques for assorting with various sensors and combining their obtained information, the theories and methods of multi-sensor fusion are required.

Multi-sensor information fusion is a basic ability of human beings. Single sensor can only provide incomplete, un-accurate, vague, uncertainty information. Sometimes, information obtained by different sensors can even be contradictory. Human beings have the ability to combine the information obtained by different organs and then make estimation and decision for environment and events. Using computer to perform multi-sensor information fusion can be considered as a simulation of the function of human brain for treating complex problems.

Multi-sensor information fusion consists of operating on the information data come from various sensors and obtaining more comprehensive, accurate, and robust results than that obtained from single sensor. Fusion can be defined as the process of combined treating of data acquired from multiple sensors, as well as assorting, optimizing and conforming of these data to increase the ability of extracting information and improving the decision capability. Fusion can extend the coverage for space and time information, reducing the fuzziness, increasing the reliability of making decision, and the robustness of systems.

Image fusion is a particular type of multi-sensor fusion, which takes images as operating objects. In a more general sense of image engineering (Zhang, 2006), the combination of multi-resolution images also can be counted as a fusion process. In this article, however, the emphasis is put on the information fusion of multi-sensor images.

BACKGROUND

There are many modalities for capture image and video, which use various sensors and techniques (Brakenhoff, 1979; Committee, 1996; Bertero, 1998), such as visible light sensor (CCD, CMOS), infrared sensor, depth sensor, con-focal scanning light microscopy (CSLM), a variety of computer tomography techniques (CT, ECT, SPECT), magnetic resonance imaging (SAR), synthesis aperture radar, millimeter wave radar (MMWR), etc.

Main Steps of Image Fusion

For image fusion, many image techniques can be used in three steps (Zhang, 2007).

Image Pre-Processing

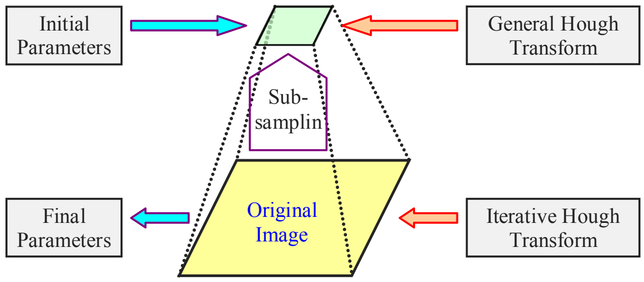
It includes image normalization (gray level equipoise, re-sampling, and interpolation), image filtering, color enhancement, edge sharpening, etc. Image fusion is carried out among images of different sizes, different resolutions, and different dynamic ranges of gray levels or colors. Image normalization is to normalize these parameters. Image filtering is to high pass filter the higher resolution image to obtain high frequency texture information, to keep it in fusion with lower resolution image. Image color enhancement is to increase the color contrast in lower resolution image, to reflect the spectrum information into the fused image. Edge sharpening is performed on high-resolution image for making the boundary clear and reducing noise, thus it fuses the space information from high-resolution image to low resolution image.

Image Registration

It is to align different images in space. In a more general sense, it is a special case of image matching, which has many existing techniques (Kropatsch, 2001; Shapiro, 2001; Buckley, 2003; Zhang, 2007). Image fusion has high requirement for accurate registration. If the registration error is higher than one pixel, then the fused results will show superposition effect and the visual quality of image will be greatly reduced.

Image registration can be classified as relative registration and absolute registration. The relative registration takes one image from many images of the same category as a reference image; other images will be aligned relatively to this reference image. Absolute registration takes the space

Figure 1. Framework for image registration using control point-based multi-scale Hough transform



coordinate system as the reference system; images to be fused will be aligned relative to this system.

Image registration can be classified also as region-based registration and feature-based registration. Control point (corresponding points in both images to be registrated) is a typical feature used in feature-based registration. Once the correspondence between control points was determined, the registration process can be carried out with determined parameters. The general Hough transform (GHT) is a commonly used technique. It can be considered as the evidence accumulation method. The global search space depends on the scale and rotation parameters, and can be very huge. To reduce the complexity of GHT, iterative Hough transform (IHT) can be used. However, IHT is influenced by the initial parameters and the range of parameter values, and often converged to local maximum. By using Hough transform in a multi-resolution decomposition environment, as shown in Figure 1, the robustness of GHT and computation efficiency of MIHT can be combined (Li, 2005).

In multi-resolution decomposition-based techniques, few control points are used in low-resolution layer in which GHT is used to obtain accurately the initial values of transform parameters. While in high resolution, IHT is used to accelerate the process.

Image Fusion

It is performed after image pre-processing and registration. The quantitative fusion is to fusion a group of data to obtain a consistent data, which is a conversion from data to data. The qualitative fusion is to fusion many single decisions to form a combined decision, which is a conversion from several uncertainty representations to a relative coherent representation. The quantitative fusion often treats information represented by numeric value while the qualitative fusion mainly treats information represented by non-numeric values.

Three Layers of Image Fusion

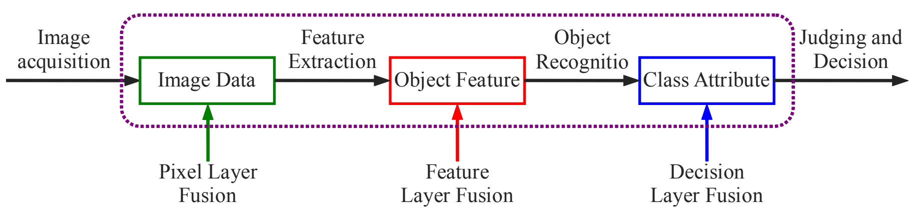
The multi-sensor image fusion can be split into three layers. They are, from low to high, pixel-based fusion layer, feature-based fusion layer, and decision-based fusion layer (Polhl, 1998). In recent years, the development tendency of fusion is going from pixel to region (Piella, 2003).

The flowchart of multi-sensor image fusion with three layers is illustrated in Figure 2. There are three steps from capturing scene image to making judgment and decision: feature extraction, object recognition, and decision creation. Three layers of image fusion are just corresponding to these three steps. The pixel-based fusion is made before the feature extraction step, the feature-based fusion is made before the object recognition step, and the decision-based fusion is made before the decision creation.

Pixel Layer Fusion

Pixel layer fusion is conducted in low layer, data layer. It operates directly on captured images and produces a single

Figure 2. Flowchart of multi-sensor image fusion



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