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Fundamentals & Applications of Image Change Detection

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Abstract

Our *Image Change Detection Toolkit* is a powerful group of algorithms useful for many applications in diverse disciplines, including remote sensing, surveillance, medical diagnosis and treatment, civil infrastructure, and underwater sensing. The main objective of the undergraduate research experience was to learn about change detection methods and the practicality of "Diverse problems, similar solutions". The first application was an environmental one in which different change detection algorithms were applied to images of underground pollutants (DNAPL). These algorithms were used to detect the area of contamination in the soil by comparing two images of the same experiment acquired at different times. Using the results, R.O.C. curves were created to compare the accuracy of the algorithms. The second application was a biological one, which required an accurate quantification of the heartbeat region of a zebra fish embryo. This information was needed to determine the location, period, frequency and phase of each pixel intensity vector that corresponded to the changing region. Finally with the use of the phase value of each pixel intensity vector, the heart beat region was segmented into two groups which were out of phase by 180 degrees. In summary, we were able to use change detection algorithms to determine the heart beat region, make quantitative measurements, and highlight the two phases of the heartbeat.

Background

The idea of using images to identify regions that have undergone some significant change is of widespread interest due to numerous amounts of applications in diverse disciplines. These areas of interest include: remote sensing, video surveillance, medical diagnosis and treatment, civil infrastructure, and underwater sensing. Even though there is a huge difference between the applications, the way to approach the problem is very similar. Every change detection method requires employing some processing steps and main algorithms. Change detection is the process of automatically identifying and analyzing regions that have undergone spatial or spectral changes from multi temporal images. Detecting and representing change provides valuable information of the possible transformations a given scene has experienced over time (Y. Oniz, 2005). The main idea is to identify the set of pixels that have undergone under some significant change between the last image of the sequence and the previous images. These groups of pixels create what is often known as the change mask. (see Figure 1).

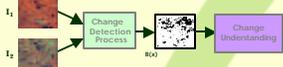


Figure 1: Change Detection diagram that shows how these algorithms work.

Overview

The main objective of the undergraduate research experience was to learn about change detection methods and the practicality of "Diverse problems, similar solutions". The first application was an environmental one in which different change detection algorithms were applied to images of underground pollutants (DNAPL), see Figure2 (S5). The second application was a biological one, which required an accurate quantification of the heartbeat region of a zebra fish embryo. This information was needed to determine the location, period, frequency and phase of each pixel intensity vector that corresponded to the changing region, see Figure2 (S1).

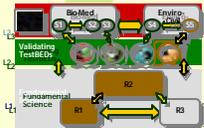


Figure 2: CenSSIS strategy diagram

Environmental Engineering

Problem Statement

Contamination of soils and groundwater resources by Dense-Non-Aqueous Phase Liquids (DNAPLs) is a severe environmental problem, which threatens the health of humans and our environment. These hazardous contaminants are difficult to locate, identify, and remove. Cross well radar is an innovative technology that is being evaluated for the detection and monitoring of DNAPLs in underground environments. Parallel technologies must, however, be developed to validate this technology. The main goal of this research is to develop an imaging system that can monitor DNAPL mass distribution in soils under transient conditions. This method necessitates the enhancement of CWR as a noninvasive technique, requiring integrated advancement in sensors (R1), physics-based signal processing and image understanding (R2), testing (L2), and field validation (L3), as envisioned by the CenSSIS strategy (Figure 2).

Application

The first application was an environmental one in which different change detection algorithms were applied to images of underground pollutants (DNAPL). The images were obtained with a monochromatic camera with Matlab's Image Acquisition Toolbox, during the second semester of 2005-06 at Prof. Ingrid Padilla's Environmental Engineering Laboratory. These algorithms were used to detect the area of contamination in the soil by comparing two images of the same scenario acquired at different times (Figure 3).



Figure 3: Change detection algorithms used to detect area of contamination in soil by comparing two images of the same scenario acquired at different times.

The same procedure was applied to the same images but with different algorithms. Some of the algorithms that were used needed two parameters in order to operate instead of one. For example the SIMDIFF_GN algorithm has two parameters that must be adjusted before the application, which are the threshold and the block size. The following figure sequence compares the change-masks for the same threshold but different block-sizes. (see Figure 4)



Figure 4: Results using SIMDIFF_GN with equal threshold (th = 0.1) but increasing block size.

Analysis

Once all the change masks were obtained with the different algorithms, the next step was to create a "Ground Truth Binary Image", that shows the real area of change. To identify the pixels that corresponded to significant change Microsoft's Paint program was used to paint with green color those pixels that show change. Then a Matlab code was written so that it would read the image with the green pixels and turn the these pixels into white and the others into black. (see Figure 5)



Figure 5: Ground Truth Binary. The true change is marked with green pixels. Then with a Matlab algorithm the green pixels are turned into white and the others into black. The result is known as the ground truth binary image.

Once a ground truth has been established, there are several standard methods for comparing the ground truth to a candidate binary change mask. For a classifier with tunable parameters, one can investigate the receiver operating characteristics (ROC) curve that plots the detection probability versus the false alarm probability to determine a desired level of performance (R. Radke, 2005). Therefore the final step was to compare the change mask with the ground truth binary image using the statistics algorithms in the Image Change Detection Toolbox, and with the results build a set of ROC curves to evaluate the performance of the algorithms. The following graphs are examples of how the ROC curves turned out for some of the algorithms.

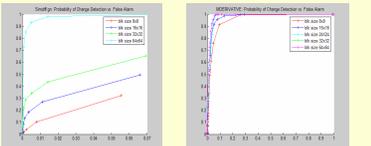


Figure 6: R.O.C. Curves show that MDERIVATIVE is a more accurate algorithm than SIMDIFF_GN

Bio-Medical Engineering

Problem Statement

Hypertension (high blood pressure) is a condition that affects more than 50 million Americans and is a leading cause of morbidity and mortality (Klabunde). At the moment in the medical industry there is only one way of treating this heart condition, which is to give direct medical treatment to the heart. Since this is a very powerful industry the prices of these medications never seem to get lower. This is why engineers in the area of bio-medical engineering are trying to figure other ways to treat this condition. One idea is arising in the Bio-Tech building at Rensselaer, under the supervision of Prof. P. Page McCaw. First they are studying the behavior between the medullary center (located in the brain) and the heart rate of the heartbeat. Therefore the main idea is to see if it is possible to target the medullary center instead of the heart, to treat patients with hypertension. (See Figure 7.a). In animal models (like zebra fish) of hypertension there are clear defects in medullary control of heart function. Zebra Fish embryos are used to study the relationship between the medullary centers and the heart rate. (See Figure 7.b)

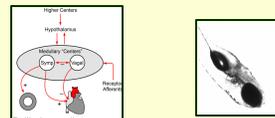


Figure 7.a: Relationship between Medullary Center and the heart.

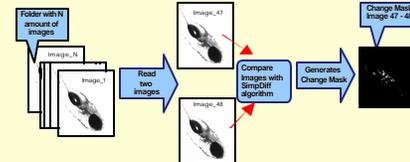


Figure 7.b: Zebra Fish.

Application

The main idea of this application was to use the change detection algorithms to create one single image that shows the heart beat region of the Zebra fish. Then use this information to determine the location, period, frequency and phase of each pixel intensity vector that corresponded to the changing region.

The first step was to use the change detection algorithms to isolate the main areas of significant change. Once all the change masks had been created for every pair of images and stored in one folder, the sub objectives at this point of the research were, see Figure 8:



The second step was to create one single change mask that shows the heart beat region of the zebra fish, see Figure 9.

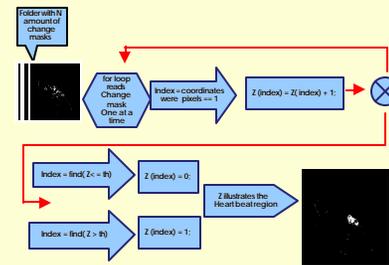


Figure 9: Diagram description on how the single change mask is created.

Eliminate all the pixels that are identified as insignificant change, due to camera vibrations, change in illumination, etc.



Figure 10: Function used to remove image noise and insignificant change. The BWMABEL function was used to identify each different Potential Heart Region (PHR) by numbering each set of connected white grouped pixels. REGIONPROPS function was utilized to delete any group of pixels that had less than 100 pixels in any connected group (dilation of noise). DILATION function was used to fill in the heart region. To make sure no pixels had been added outside the border of the Heart, the EROSION function was performed.

Determine the pixel intensity vectors from the heart beat region. Pt turns out to be a matrix in which each line vector contains the intensity values of one pixel for all the N images.

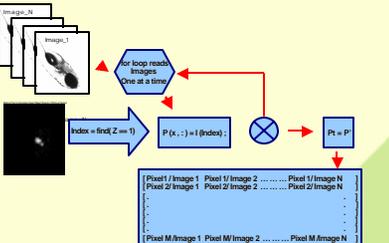


Figure 11: Pixel intensity vector diagram

A zero-crossing method was used to determine the period in terms of images for each pixel intensity vector. Then this value was multiplied by the sampling rate to change the period to seconds. Also the frequency in Hz was determined by inverting the period value.

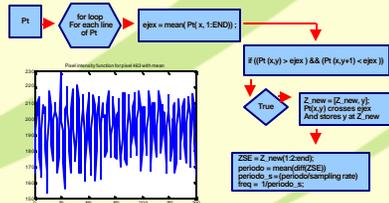


Figure 12: Period and frequency calculation using zero crossings

Also, the first maximum of each pixel intensity vector was determined to obtain the phase value in terms of images.

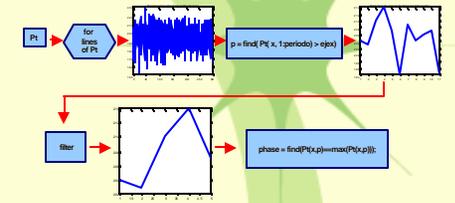


Figure 12: Phase calculation using first maximum of each vector

We construct a table that contains the location, period, phase and frequency of each pixel intensity vector.

Pixel Number	Column Coordinate	Line Coordinate	Pixel Period in terms of images	Pixel Period in seconds	Phase	Frequency in Hz
1	1	1	1	0.0001	0	10000
2	1	2	1	0.0001	0	10000
3	1	3	1	0.0001	0	10000
4	1	4	1	0.0001	0	10000
5	1	5	1	0.0001	0	10000
6	1	6	1	0.0001	0	10000
7	1	7	1	0.0001	0	10000
8	1	8	1	0.0001	0	10000
9	1	9	1	0.0001	0	10000
10	1	10	1	0.0001	0	10000
11	1	11	1	0.0001	0	10000
12	1	12	1	0.0001	0	10000
13	1	13	1	0.0001	0	10000
14	1	14	1	0.0001	0	10000
15	1	15	1	0.0001	0	10000
16	1	16	1	0.0001	0	10000
17	1	17	1	0.0001	0	10000
18	1	18	1	0.0001	0	10000
19	1	19	1	0.0001	0	10000
20	1	20	1	0.0001	0	10000
21	1	21	1	0.0001	0	10000
22	1	22	1	0.0001	0	10000
23	1	23	1	0.0001	0	10000
24	1	24	1	0.0001	0	10000
25	1	25	1	0.0001	0	10000
26	1	26	1	0.0001	0	10000
27	1	27	1	0.0001	0	10000
28	1	28	1	0.0001	0	10000
29	1	29	1	0.0001	0	10000
30	1	30	1	0.0001	0	10000
31	1	31	1	0.0001	0	10000
32	1	32	1	0.0001	0	10000
33	1	33	1	0.0001	0	10000
34	1	34	1	0.0001	0	10000
35	1	35	1	0.0001	0	10000
36	1	36	1	0.0001	0	10000
37	1	37	1	0.0001	0	10000
38	1	38	1	0.0001	0	10000
39	1	39	1	0.0001	0	10000
40	1	40	1	0.0001	0	10000
41	1	41	1	0.0001	0	10000
42	1	42	1	0.0001	0	10000
43	1	43	1	0.0001	0	10000
44	1	44	1	0.0001	0	10000
45	1	45	1	0.0001	0	10000
46	1	46	1	0.0001	0	10000
47	1	47	1	0.0001	0	10000
48	1	48	1	0.0001	0	10000
49	1	49	1	0.0001	0	10000
50	1	50	1	0.0001	0	10000
51	1	51	1	0.0001	0	10000
52	1	52	1	0.0001	0	10000
53	1	53	1	0.0001	0	10000
54	1	54	1	0.0001	0	10000
55	1	55	1	0.0001	0	10000
56	1	56	1	0.0001	0	10000
57	1	57	1	0.0001	0	10000
58	1	58	1	0.0001	0	10000
59	1	59	1	0.0001	0	10000
60	1	60	1	0.0001	0	10000
61	1	61	1	0.0001	0	10000
62	1	62	1	0.0001	0	10000
63	1	63	1	0.0001	0	10000
64	1	64	1	0.0001	0	10000
65	1	65	1	0.0001	0	10000
66	1	66	1	0.0001	0	10000
67	1	67	1	0.0001	0	10000
68	1	68	1	0.0001	0	10000
69	1	69	1	0.0001	0	10000
70	1	70	1	0.0001	0	10000
71	1	71	1	0.0001	0	10000
72	1	72	1	0.0001	0	10000
73	1	73	1	0.0001	0	10000
74	1	74	1	0.0001	0	10000
75	1	75	1	0.0001	0	10000
76	1	76	1	0.0001	0	10000
77	1	77	1	0.0001	0	10000
78	1	78	1	0.0001	0	10000
79	1	79	1	0.0001	0	10000
80	1	80	1	0.0001	0	10000
81	1	81	1	0.0001	0	10000
82	1	82	1	0.0001	0	10000
83	1	83	1	0.0001	0	10000
84	1	84	1	0.0001	0	10000
85	1	85	1	0.0001	0	10000
86	1	86	1	0.0001	0	10000
87	1	87	1	0.0001	0	10000
88	1	88	1	0.0001	0	10000
89	1	89	1	0.0001	0	10000
90	1	90	1	0.0001	0	10000
91	1	91	1	0.0001	0	10000
92	1	92	1	0.0001	0	10000
93	1	93	1	0.0001	0	10000
94	1	94	1	0.0001	0	10000
95	1	95	1	0.0001	0	10000
96	1	96	1	0.0001	0	10000
97	1	97	1	0.0001	0	10000
98	1	98	1	0.0001	0	10000
99	1	99	1	0.0001	0	10000
100	1	100	1	0.0001	0	10000

Figure 13: Table with all the results. Pixel number, pixel coordinate, period in terms of images, period in seconds, phase and frequency

The final step was to divide the heart beat region into two main areas. To identify the two main areas the phase values of each pixel intensity vector were used to differentiate the pixels that are in one phase from the ones that were out of phase.

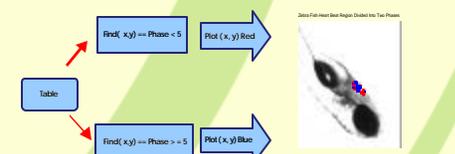


Figure 14: Diagram that shows heart beat region divided into two phase groups

Conclusions

- CenSSIS's Image Change Detection Toolbox is an example of how diverse problems can be solved with similar solutions.
- The image processing change detection algorithms can be used to detect contaminated soil regions in a 2-D soil cell. Also these can be used to isolate the heart beat region of the zebra fish.
- Using the information obtained with the algorithms, the period, phase and frequency values of each pixel intensity vector can be calculated.
- Finally with the corresponding phase values of the pixel intensity vector, the heart beat region can be divided into two main areas.

Opportunities for Technology Transfer