arpa_summ.admin

1. ARPA ORDER NUMBER: A423

2. CONTRACT/GRANT NUMBER: N00014-93-1200

3. AGENT:Office of Naval Research

4. CONTRACT TITLE: Outdoor Landmark Recognition Using Hybrid Fractal Vision System and Neural Networks.

5. CONTRACTOR/ORGANIZATION: North Carolina State University

6. SUBCONTRACTORS: None

7. CO-PRINCIPAL INVESTIGATORS: None

8. ACTUAL START DATE: 1 October 1993

9. EXPECTED END DATE: 30 September 1996

10. FUNDING PROFILE:not available
10.1 Current contract: $305,052

FY 93-94	$84,574
FY 94-95	$103,585
FY 95-96	$116,893
Total	$305,052

10.2 Options (not exercised): None

10.3 Total funds provided for all years: $305,052
Total funds expended to date: Nil
As of date: 1 July 1994

10.4 Date current funding will be expended: 30 September 1996
10.5 Funds required in FY94: $103,585

11. ANYTHING ELSE YOU NEED (FROM ARPA): Outdoor FLIR images for more experimental testing.

arpa.summ

ORGANIZATION: North Carolina State University

SUBCONTRACTORS: None

PRINCIPAL INVESTIGATORS: Dr Ren C. Luo, luo@eos.ncsu.edu. 919/515-5199 (w)

TITLE OF EFFORT: Outdoor Landmark Recognition Using Hybrid Fractal Vision System and Neural Networks.

OBJECTIVE: Landmarks are useful cues for auotnomous mobile robot navigation. Due to the changing imaging conditions, the appearance of the landmarks is varying in outdoor environments. We will develop a novel system to detect and recognize the landmarks. The developed system will be able to overcome changes in scale, lighting, etc.

APPROACH:
The proposed approach is based on a two-step method,using both fractal based object classifier and neural network based object identifier. Since fractals are inherently scale invariant over a finite range of scales, they make good models for outdoor scene objects. Since neural networks have fast recognition capabilities, they are a good choice in real time mobile robot applications.

Fractal models: Mandelbrot defined a fractal surface to be one in which the Hausdorff-Besicovitch dimension is greater than the topological dimension. Most natural surfaces, such as coastlines, brick, skin, rocks, can be modeled as fractal surfaces. Then the segmentation problem is reduced to estimating this fractal dimension.

We propose a new approach to the measurement of the fractal dimension based on the increments of the fBM. By choosing an appropriate increment, we can derive a simple relationship between the image statistics and the fractal dimension. We define Incremental Fractional Brownian Motion (IFBM) for discrete time as follows: if $B(n)$ is Brownian motion, then the ifBM of order m, $I_m(n)$, is given by

$$I_m(n) = B(n) - B(n-m)$$

The autocorrelation of the ifBM is given by

$$R_{II}(n+k,n) = E[I_m(n+k)I_m(n)]$$

Since the IFBM is a stationary process, the autocorrelation must be a function of the time shift or in other words the difference, $(n+k) - (n) = k$. Substituting the FBM terms for $I_m(n)$ gives

$$R_{II}(k) = E[\{B(n+k) - B(n+k-m)\}\{B(n) - B(n-m)\}]$$

The autocorrelation can be simplified to result in the following relationship between the fractal dimension and the moments:

$$(2H-1)\ln(2) = \ln[R_{II}(1)/(\sigma^2) + 1].$$

Or, in other words, the fractal dimension is proportional to the ratio of the autocorrelation at distance of 1 and the variance. For smooth surfaces, the autocorrelation is quite flat, resulting in a value close to 1 for the ratio; for rough surfaces the autocorrelation drops off rapidly and the ratio will be much smaller. The resulting fractal dimension $D = 3-H$ will therefore be higher for rough surfaces than for smooth surfaces. This is in accordance with our observations of nature.

Neural Network models: A new neural network model, called the Reconfigurable Neural Network (RNN) model, is proposed with new update rules that incorporate learning stability. This network model is based on self-organization. The training algorithm attempts to find an optimal cover of the input space by the neurons. Training is concluded when the neuron assigned to each pattern class is at an average minimum distance to all presented patterns of that class. Reconfigurability is invoked when new objects that were not seen during the training phase appear during the testing phase. In this case, the additional neurons are used to integrate them into the memory of the network.

If the variance within the input data set is low, then one neuron may move much closer to the data than any of the other neurons. The network will then consistently have the same output for all the inputs, i.e., the network will fail to learn the patterns. With RNN, a novel approach is used to tackle this oscillations problem. The weight space is initially flooded with an excess of neurons, generally a multiple of the number of classes. This causes each neuron to concentrate on a very small part of the input space and prevents network saturation of the type discussed above.

The additional neurons in the weight space that have not been used to represent any class can still be used when new classes are to be introduced. Since the variance within a class is high, due to the severe distortions, more than one neuron is expected to be required to cover the class. However, each class is expected to be a well defined cluster. Hence, when there are sufficient neurons to adequately cover each class, a further increase in the number of neurons is not expected to affect the learning rate of the network.

PROGRESS: We have developed a mathematical model for Incremental Fractional Brownian Motion (IFBM). We have proved that the IFBM model is intensity invariant. Currently we are working on the evaluation of the performance of IFBM the model with images of natural scenes. We also are working on the segmentation to single out the landmark from the cluttered outdoor scenes.

FY94 ACCOMPLISHMENTS:
- Developement of mathematical model for IFBM.
- Proof of intensity invariance of IFBM.
- Statistical analysis of estimated parameters for goodness-of-fit analysis.
- Demonstrated scale and intensity invariance of IFBM using outdoor images.

FY-95 PLANS:
- Development of reconfigurable neural network architecture.
- Proofs of convergence and optimality of network learning algorithms.
- Investigation of error variance and bounds.
- Performance analysis and training experiments with various training sets.
- Preliminary test using outdoor scene landmark image as input to demonstrate the performance of reconfigurable neural network.

TECHNOLOGY TRANSITION: None so far.

PUBLICATIONS: "Outdoor Landmark Recognition using Fractal Based Vision and Neural Networks" by Ren C. Luo, Harsh Potlapalli and David W. Hislop, in Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems, July 27-30,1993, Yokohama, Japan.

DATE PREPARED: 1 July 1994

arpa_summ.sigevent

SIGNIFICANT EVENTS

Development of Fractal Vision and Experimental Tests Using Natural Textures Image Data

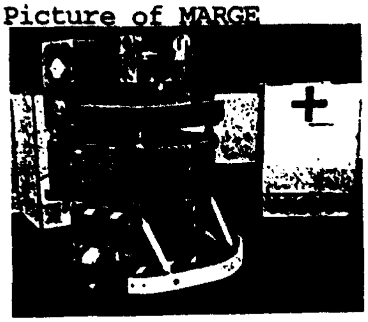
A fractal theory model for natural textures, called the Incremental Fractional Brownian Motion (IFBM) model was developed for analysis of natural textures in outdoor environments under widely varying imaging conditions. The computational complexity of this model is lower than comparable models in the literature. This model is robust under changes of scale and incident light conditions. The parameters estimated via this model has been shown to be good fits for the observed data.

Fractals are useful texture measurement features since they are inherent to the surface. Fractal dimensions are scale invariant and are therefore useful tools in dynamic environments. We have been able to prove that the fractal dimension of a smooth surface in N-dimensional space must be N and that of a fractal surface in the same space must be between N and N+1. Generally, the rougher a surface, the higher its fractal dimension. In the IFBM model, the fractal parameter,H, is expressed as a ratio of the autocorrelation and the variance. For rough surfaces the autocorrelation drops off rapidly leading to a lower ratio than compared to smooth surfaces where the autocorrelation is relatively flat. The fractal dimension estimate is expressed as a 3-H which leads to the conclusion that the fractal dimension for rough surfaces will be higher than for smooth surfaces. This is also supported by observations of the natural scenes. Since the fractal parameter is expressed as a ratio, the estimate is invariant to changes in signal amplitude such as increases in light intensity.

We have implemented this concept and theoretical foundation of IFBM model using natural textures image data. As a result, we have demonstrated the effectiveness of segmenting landmark scene from the cluttered natural scene.

arpa.quad

Picture of MARGE



MARGE (Mobile Autonomous Robot for Guidance Experiments)

NEW IDEAS

1. Robust Fractal Based Vision Model
2. Proofs of Invariance on Scale and light intensity
3. Efficient Reconfigurable Neural Network for Landmark Recognition

IMPACT

1. Enhance Navigation Capability for UGV in Outdoor Environment
2. Enhance Automated Target Recognition Capability in cluttered Outdoor scene
3. Proofs as an Effective New Alternations for Natural Scene Understanding

SCHEDULE

93----------94----------95-----------96
(fractals) (neural nets) (implement.)