Infrared Image Enhancement Using Wavelet Transform

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Abstracts

In Infrared Image Enhancement using Wavelet Transform, two enhancement algorithms namely spatial and spatiotemporal homomorphic filtering (SHF and STHF) have been given for enhancement of the far infrared images based upon a far infrared imaging model. Although spatiotemporal homomorphic filtering may reduce the number of iterations greatly in comparison to spatial one for a similar degree of convergence by making explicit use of the additional information provided temporally, the enhanced results from SHF are in general better than those from STHF. In this dissertation work an additive wavelet transform will be proposed for enhancement and filtration of homomorphic infrared images.

Keywords: Infrard Images, Additive Wavelet transform, Homomorphic Image Enhancement,

1. Introduction

Infrared (IR) light is electromagnetic radiation with a wavelength longer than that of visible light, measured from the nominal edge of visible red light at 0.74 micrometers, and extending conventionally to 300 micromeres. These wavelengths correspond to a frequency range of approximately 1 to 400 THz, and include most of the thermal radiation emitted by objects near room temperature. Microscopically, IR light is typically emitted or absorbed by molecules when they change their rotational-vibrational movements. Sunlight at zenith provides an irradiance of just over 1 kilowatt per square meter at sea level. Of this energy, 527 watts is infrared radiation, 445 watts is visible light, and 32 watts is ultraviolet radiation. Fig1.1 shows an example of an infrared image in mid infrared light.

Infrared imaging is used extensively for military and civilian purposes. Military applications include target acquisition, surveillance, night vision, homing and tracking. Non-military uses include thermal efficiency analysis, remote temperature sensing, short-ranged wireless communication, spectroscopy, and weather forecasting. Infrared astronomy uses sensor-equipped telescopes to penetrate dusty regions of space, such as molecular clouds; detect objects such as planets, and to view highly red-shifted objects from the early days of the universe.

Humans at normal body temperature radiate chiefly at wavelengths around 12 µm (micrometers), At the atomic level, infrared energy elicits vibrational modes in a molecule through a change in the dipole moment, making it a useful frequency range for study of these energy states for molecules of the proper symmetry. Infrared spectroscopy examines absorption and transmission of photons in the infrared energy range, based on their frequency and intensity.

Different regions in the infrared

Objects generally emit infrared radiation across a spectrum of wavelengths, but sometimes only a limited region of the spectrum is of interest because sensors usually collect radiation only within a specific bandwidth. Therefore, the infrared band is often subdivided into smaller sections.

A commonly used sub-division scheme is:

- *Near-infrared* (NIR, IR-A *DIN*)

0.75-1.4 µm in wavelength, defined by the water absorption, and commonly used in fiber optic telecommunication because of low attenuation losses in the SiO_2 glass (silica) medium. Image intensifiers are sensitive to this area of the spectrum. Examples include night vision devices such as night vision goggles.

- *Short-wavelength infrared* (SWIR, IR-B *DIN*): 1.4-3 µm, water absorption increases significantly at 1,450 nm. The 1,530 to 1,560 nm range is the dominant spectral region for long-distance telecommunications.

- *Mid-wavelength infrared* (MWIR, IR-C *DIN*) also called intermediate infrared (IIR): 3-8 µm. In guided missile technology the 3-5 µm portion of this band is the atmospheric window in which the homing heads of passive IR 'heat seeking' missiles are designed to work, homing on to the Infrared signature of the target aircraft, typically the jet engine exhaust plume.

- *Long-wavelength infrared* (LWIR, IR-C *DIN*): 8–15 µm. This is the "thermal imaging" region, in which sensors can obtain a completely passive picture of the outside world based on thermal emissions only and requiring no external light or thermal source such as the sun, moon or infrared illuminator. Forward-looking infrared (FLIR) systems use this area of the spectrum. Sometimes also called the "far infrared."

- *Far infrared* (FIR): 15 - 1,000 µm NIR and SWIR is sometimes called "reflected infrared" while MWIR and LWIR is sometimes referred to as "thermal infrared." Due to the nature of the blackbody radiation curves, typical 'hot' objects, such as exhaust pipes, often appear brighter in the MW compared to the same object viewed in the LW.

Images received through various infrared (IR) devices in many applications are distorted due to the atmospheric aberration mainly because of atmospheric variations and aerosol turbulence [1], [2]. In the dissertation work, new algorithmic strategies have been presented to enhance the visual quality of IR images. The idea is to model the IR image pixels as an input output system with IR image as the input and a “similar” optical image as the output. The image modeling is carried out using the usual system identification strategies. The system identification problem is to estimate a model of a system based on observed input-output data. Several ways to describe a system and to estimate such descriptions exist and are being used in various applications.

The identification process amounts to repeatedly selecting a model structure, computing the best model in the structure, and evaluating this model’s properties to see if they are satisfactory. The cycle can be itemized as follows [3], [4].

1. Design the experiment to collect input-output data from the system to be identified.
2. Select and define a model structure (a set of candidate system descriptions) within which a model is to be found. This would mean the order and number of unknown coefficients be identified and tuned to fit the data.
3. Compute the best model in the model structure according to the input-output data and a given criterion of fit. In other words, fine tuning the coefficient values to get the most optimal values under a given optimality criterion.
4. If the model is good enough, then stop; otherwise, go back to Step 3 to try another model set. Possibly also try other estimation methods.

The enhancement of infrared images is slightly different from traditional image enhancement in dealing with the large black areas and the small details. So, our suggested approach aims at separating the details in different subbands and processing each subband, separately. We have found that the additive wavelet transform is a powerful tool in image decomposition. If the infrared image is decomposed using the additive wavelet transform, the details can be separated into the higher frequency subbands. Also, we use the homomorphic enhancement algorithm for transforming these details to illumination and reflectance components. Then, the reflectance components are amplified showing the details, clearly. Finally a wavelet reconstruction process is performed to get an enhanced infrared image with much more details.

2. Litrature Review

Dim target detection is particularly challenging because standard techniques such as spatial thresholding, CFAR detection, and edge detection can fail due to the lack of contrast between target and background. To detect targets in clutter, there must be a set of characteristics that can be exploited to separate targets from clutter. Separation can be based on characteristics such as scale, shape, texture, pixel value dynamic range, pixel value statistical distribution, spatial frequency, brightness, and contrast differences.

Qi, H. and J. F. Head [1] suggested that Wavelets have demonstrated some effectiveness for target detection. Traditionally, there are four primary applications of wavelet-based methods to target detection: These are

1. Wavelets as edge detectors;
2. Using wavelets to separate targets from clutter based on scale differences;
3. Using wavelets as approximate matched filters;
4. Capturing target dynamic range differences using wavelet filters.

Using wavelets as edge detectors assumes that target edges differ in some way from clutter edges. For example, edges from natural clutter may be more diffuse whereas edges from man-made objects such as vehicles may be harder, sharper, and more distinct. Kuruganti, P. T. and H. Qi [2] and Scales, N., C. Herry, and M. Frize [3] stated as edge detectors, wavelets may be designed to capture these edge differences. Zhang, C. J., F. Yang [4] stated that targets may also differ from clutter by characteristic scales. For scale separation,

A priori knowledge of target or clutter characteristic scales may be exploited. Wavelet coefficients containing significant energy at clutter scales (or non-target scales) may be filtered out. Andreone, L., P. C. Antonello and M. Bertozzi [5] stated thatwavelets can be also designed to function as approximate matched filters. For such usage, wavelet filters are designed to produce a large response when matched against a target region. Lastly, the low and high pass filters from the wavelet decomposition can be used to detect target regions of low or high pixel value dynamic range. Dim targets occur in low dynamic range regions; regions of high dynamic range can be rejected. Image enhancement is a very popular field in image processing. Enhancement aims at improving the visual quality of an image by reinforcing edges and smoothing flat areas. Several researchers have evaded this field using different approaches such as simple filtering, adaptive filtering, wavelet denoising, homomorphic enhancement etc. All these approaches concentrate on reinforcing the details of the image to be enhanced.

Infrared image processing is a new field emerging for the evolution of night vision cameras. It also has applications in thermal medical imaging. This evolution of night vision cameras has encouraged the research in infrared image enhancement for information extraction from these images. These images have a special nature of large black areas and small details due to the absence of the appropriate amount of light required for imaging. So, the main objective is to reinforce the details to get as more image information as possible.

3. Analysis of problem

Images received through various infrared (IR) devices in many applications are distorted due to the atmospheric aberration mainly because of atmospheric variations and aerosol turbulence [1].

The night vision cameras have encouragedthe research in infrared image enhancement for information extractionfrom these images. These images have a special nature of large blackareas and small details due to the absence of the appropriate amountof light required for imaging. So, the main objective is to reinforce thedetails to get as much details as possible.The system identification problem is to estimate a model of a system based on observed input-output data. Several ways to describe a system and to estimate such descriptions exist and are being used in various applications. Here we are going to Enhance the images generated by various Infrared Devices those Images are having very less information by enhancing these images we will get more and more information, for enhancement we will use Additive Wavelet Transform Algorithm and Homomorphic Enhancement algorithm by using these algorithm we can enhance the images .

A. Additive Wavelet Transform Algorithm:

The additive wavelet transform decomposes an image into subbands using the “a’ trous” filtering approach [6–8] in several consecutive stages. The low pass filter used in this process has the following mask for all stages :

Each difference between filter outputs of two consecutive stages is a subband of the original image. We can use these subbands for further processing using homomorphic enhancement.

B. Homomorphic Enhancement Algorithm:

An image can be used represented as a product of tow components as in the following equation

$$f(n1,n2)=i(n1,n2)r(n1,n2) \qquad (2)$$

where $f(n1, n2)$ is the obtained image pixel value, $i(n1, n2)$ is the light illumination incident on the object to be imaged and $r(n1, n2)$ is the reflectance of that object. It is known that illumination is approximately constant since the light falling on all objects is approximately the same.

The only change between object images is in the reflectance component. If we apply a logarithmic process on Eq. (2), we can change the multiplication process into an addition process as follows:

$$\log(f(n1,n2))=\log(i((n1,n2))+\log(r(n1,n2) \quad (3)$$

The first term in the above equation has small variations but the second term has large variations as it corresponds to the reflectivity of the object to imaged. By attenuating the first term and reinforcing the second term of Eq. (3), we can reinforce the image details.

4. Proposed work and objectives

*A. **Proposed Work:***

In the proposed dissertation work infrared image enhancement using additive wavelet transform will be implemented. The dissertation work will be carried out in following steps.

1. ***Analysis of available infrared image enhancement algorithms.***

In this Step we will analyse the input Infrared images which we have to enhance and after analysis we have to follow next step that is step 2

2. ***Decomposing the infrared image into various bands using additive wavelet transform.***

In this step we will decompose the infrared image into four subbands $p3$, $w1$, $w2$ and $w3$ using the additive wavelet transform and the lowpass mask of Eq. (1).

3. ***Extracting illumination and reflectance components of each subband***

In this step we will Extract Illumination and Reflectance component of each subbands generated in the step 2 by doing Additive Wavelet Transposition, We will call this process as Homomorphic Enhancement Processing.

4. ***A Reinforcement operation***

In step 4 we will do the reinforcement of the components, obtained after homomorphic processing, the reflectance component in each subband and attenuation operation of the illumination component from the Homomorphic processing.

5. ***Reconstruction of separated bands***

In step 5 we will do the Reconstruction of separated bands from its illumination and reflectance using addition and exponentiation processes. All the subbands, w'_1, w'_2,w'_3 and p_3 are added which will give $f'(n_1,n_2)$.

6. ***Inverse wavelet Transform***

Finally, by applying inverse additive wavelet transform on the obtained subbands by adding components after Homomorphic Processing. we will get the new enhance image having more generative information.

*B. **Objectives***

- To reinforce the details to get as more image information as possible.
- To compare the enhancement algorithm results with previously implemented infrared image enhancement algorithm.
- To check the efficiency of new enhanced image.

5. Applications

There are following applications of the infrared images where enhanced images can be used for better use of information.

a) Tracking

Infrared tracking, also known as infrared homing, refers to a passive missile guidance system which uses the emission from a target of electromagnetic radiation in the infrared part of the spectrum to track it. Missiles which use infrared seeking are often referred to as "heat-seekers", since infrared (IR) is just below the visible spectrum of light in frequency and is radiated strongly by hot bodies. Many objects such as people, vehicle engines, and aircraft generate and retain heat, and as such, are especially visible in the infrared wavelengths of light compared to objects in the background.

b) Heating

Infrared radiation can be used as a deliberate heating source. For example it is used in infrared saunas to heat the occupants, and also to remove ice from the wings of aircraft (de-icing). FIR is also gaining popularity as a safe heat therapy method of natural health care & physiotherapy. Infrared can be used in cooking and heating food as it predominantly heats the opaque, absorbent objects, rather than the air around them. Infrared heating is also becoming more popular in industrial manufacturing processes, e.g. curing of coatings, forming of plastics, annealing, plastic welding, print drying. In these applications, infrared heaters replace convection ovens and contact heating. Efficiency is achieved by matching the wavelength of the infrared heater to the absorption characteristics of the material.

c) Communication

IRdata transmission is also employed in short-range communication among computer peripherals and personal digital assistants. These devices usually conform to standards published by IrDA, the Infrared Data Association. Remote controls and IrDA devices use infrared light-emitting diodes (LEDs) to emit infrared radiation which is focused by a plastic lens into a narrow beam. The beam is modulated, i.e. switched on and off, to encode the data. The receiver uses a silicon photodiode to convert the infrared radiation to an electric current. It responds only to the rapidly pulsing signal created by the transmitter, and filters out slowly changing infrared radiation from ambient light. Infrared communications are useful for indoor use in areas of high population density. IR does not penetrate walls and so does not interfere with other devices in adjoining rooms. Infrared is the most common way for remote controls to command appliances. Infrared remote control protocols like RC-5, SIRC, are used to communicate with infrared.

Free space optical communication using infrared lasers can be a relatively inexpensive way to install a communications link in an urban area operating at up to 4 gigabit/s, compared to the cost of burying fiber optic cable.

Infrared lasers are used to provide the light for optical fiber communications systems. Infrared light with a wavelength around 1,330 nm (least dispersion) or 1,550 nm (best transmission) are the best choices for standard silica fibers.

IR data transmission of encoded audio versions of printed signs is being researched as an aid for visually impaired people through the RIAS (Remote Infrared Audible Signage) project.

d) Spectroscopy

Infrared vibrational spectroscopy (see also near infrared spectroscopy) is a technique which can be used to identify molecules by analysis of their constituent bonds. Each chemical bond in a molecule vibrates at a frequency which is characteristic of that bond. A group of atoms in a molecule (e.g. CH_2) may have multiple modes of oscillation caused by the stretching and bending motions of the group as a whole. If an oscillation leads to a change in dipole in the molecule, then it will absorb a photon which has the same frequency. The vibrational frequencies of most molecules correspond to the frequencies of infrared light. Typically, the technique is used to study organic compounds using light radiation from 4000–400 cm^{-1}, the mid-infrared. A spectrum of all the frequencies of absorption in a sample is recorded. This can be used to gain information about the sample composition in terms of chemical groups present and also its purity (for example a wet sample will show a broad O-H absorption around 3200 cm^{-1}).

e) *Meterology*

A frontal system can be seen in the Gulf of Mexico with embedded Cumulonimbus cloud. Shallower Cumulus and Stratocumulus can be seen off the Eastern Seaboard.

Weather satellites equipped with scanning radiometers produce thermal or infrared images which can then enable a trained analyst to determine cloud heights and types, to calculate land and surface water temperatures, and to locate ocean surface features. The scanning is typically in the range 10.3-12.5 µm (IR4 and IR5 channels).

High, cold ice clouds such as Cirrus or Cumulonimbus show up bright white, lower warmer clouds such as Stratus or Stratocumulus show up as grey with intermediate clouds shaded accordingly. Hot land surfaces will show up as dark grey or black. One disadvantage of infrared imagery is that low cloud such as stratus or fog can be a similar temperature to the surrounding land or sea surface and does not show up. However, using the difference in brightness of the IR4 channel (10.3-11.5 µm) and the near-infrared channel

(1.58-1.64 μm), low cloud can be distinguished, producing a *fog* satellite picture. The main advantage of infrared is that images can be produced at night, allowing a continuous sequence of weather to be studied.

These infrared pictures can depict ocean eddies or vortices and map currents such as the Gulf Stream which are valuable to the shipping industry. Fishermen and farmers are interested in knowing land and water temperatures to protect their crops against frost or increase their catch from the sea. Even El Niño phenomena can be spotted. Using color-digitized techniques, the gray shaded thermal images can be converted to color for easier identification of desired information.

f) Other Imaging

In infrared photography, infrared filters are used to capture the near-infrared spectrum. Digital cameras often use infrared blockers. Cheaper digital cameras and camera phones have less effective filters and can "see" intense near-infrared, appearing as a bright purple-white color. This is especially pronounced when taking pictures of subjects near IR-bright areas (such as near a lamp), where the resulting infrared interference can wash out the image. There is also a technique called 'T-ray' imaging, which is imaging using far-infrared or terahertz radiation. Lack of bright sources makes terahertz photography technically more challenging than most other infrared imaging techniques. Recently T-ray imaging has been of considerable interest due to a number of new developments such as terahertz time-domain spectroscopy.

5. Conclusion

We will give the new approach for infrared image enhancement. This approach will combine both of the Homomorphic Enhancement and the wavelet transforming algorithm's features.

The homomorphic processing is applied to the infrared image subbands, separately. Then, these subbands are merged again to reconstruct an enhanced image. The results obtained using this algorithm reveal its ability to enhance infrared images.The newly generated image will be having an efficient information which is essential to the user.

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