**Remote Sensing – Revision Questions**

1. **Why is an image algebraic operation also called a multi-image point operation? Write down the mathematical definition of the multi-image point operation.**

**P.8 Lecture 2**

Algebraic operations are performed on each ith pixel, across all the bands, j without considering neighbouring pixels within the ith pixel’s band j. For example, a 3-band (j=3) addition would sum up the ith pixel (DN number) in each jth band into a new 1-band image where the 1st pixel = DNi=1, j=1 + DNi=1, j=2 + DNi=1, j=3

Where n = number of bands

1. **Why does image addition improve image SNR? Using a stationary camera to take 9 pictures of the same scene under identical illumination conditions and then summing them to then generate an average image, by how many times is the SNR is improved in comparison with any an individual picture?**

**P.11 Lecture 2**

Image addition improves an images SNR as it **averages out the random noise** (assumed to be distributed randomly across the image pixels) in each individual image, suppressing it.

For n duplications of an image, each contaminated by the same level of random noise, the SNR of the summation image is increased by ~ times:

For example, the summed image of 9 images of the same scene under identical illumination conditions will have 3xSNR ( ) of the individual (9) images.

1. **Describe image difference (subtraction) and ratio (division) operations and compare the two techniques in terms of change detection, selective enhancement and processing efficiency.**

**P.13, 14, 18-22 Lecture 2**

Image difference (subtraction) =

A pixel-wise operation between bands i and j.

Image difference is used for selective **spectral enhancement**, **change detection** and **removal of background illumination bias**. However, it does reduce the image information and decreases SNR.

Image ratio =

Image ratios are designed to highlight target features in high value DNs. Image ratios are useful for **selective enhancement of spectral features** (spectral enhancement). Ratios are also able to **suppress topographic shading**. Ratios reduce SNR significantly.

1. **What is the importance of the weights in image subtraction? Suggest the most desirable pre-processing step for image differencing…**

**P.13 Lecture 2**

The weights wi and wj of bands i and j are important to ensure **balanced differencing**. If one band’s brightness is significantly higher, the differenced image will be dominated by the brighter one.

Normalising the DNs (brightness values) of the pixels between [**0, 1**] is a desired pre-processing step for image differencing.

1. **Why does image differencing decrease the SNR?**

**P.13 Lecture 2**

Subtracting two images **removes the common features** whilst **retaining the random noise** in each image. Therefore, decreasing the SNR.

1. **Describe image multiplication and its major application.**

**P.17 Lecture 2**

Image multiplication =

Image multiplication is performed pixel-wise i.e. band i’s DN x band j’s DN.

Key Applications:

* **Masking**: An image (band) can be used to remove part of another image (band) i.e. by having DN values between 0 and 1 in band i, any pixel in j multiplied by a DNi=0 will be 0 in j.
* **Modulation:** An image can be modulated by another i.e. topographic shading can be added to a coloured (flat) map using a panchromatic image.

1. **Explain the characteristics of the value range of a ratio image. Do you think that two reciprocal ratio images contain the same information when displayed after a linear stretch, and explain why?**

**P.19 Lecture 2**

Note: In image ratios, you need to shift the value range (by adding 1) to avoid zero division.

The output image ratio Y (= ) where Xi has a DN (8-bit) range [1, A] and Xj has a DN range of [1, B], the output image will have a range [1/B, A/B]. This is inversed ([1/A, B/A]) if the division is inversed. Depending on the DN range in band i or j, the range of DN in the ratio image will be much different whilst containing the same information. If you linear stretch an already wide range, you are likely to get information loss.

For example,

Consider band i a 3x3 [[1, 1, 1], [1, 1, 1], [1, 1, 1]] and a band j 3x3: [[255, 255, 255], [255, 255, 255], [255, 255, 255]], the image Y (i/j) will have a range [1/255, 255] whereas the inverse (j/i) will have a range [1, 255], much smaller.

Typically, **make the brighter band the numerator**.

1. **Using a diagram to describe ratio image as a coordinate transformation from a Cartesian coordinates system to a polar coordinates system.**

**\*\*See Philippa’s email for slide missed from lectures.**

1. **Explain the principle of topographic suppression using image ratio technique. selected.**

**P.21 Lecture 2 (see slide for explicit ratios)**

If we consider 2-pixel DNs for 2 bands i and j, where DN1 receives **n times more illumination** **than DN2** then when we find the ratio of the bands i and j for DN1 and DN2, the n factor cancels out in the illumination case when dividing the DN1i / DN1j. This cancelling out suppresses the topographic shading from the illumination.

The DNs in different spectral bands of a multi-spectral image are proportional to the solar radiation received by land surface and its spectral reflectance.

1. **What is the NDVI and how is it designed? Explain the different functionalities of differencing and ratio operations.**

**P.24 Lecture 2**

NDVI is the Normalised Difference Vegetation Index and is defined as:

Healthy vegetation has a high reflection **peak** **in** **NIR** and an absorption **trough in red** because of the spectral properties of chlorophyll. This **significant difference in brightness between NIR and R bands is called the red edge** and is a unique spectral property that makes photosynthesising vegetation identifiable from other ground objects. **NDVI is an index that takes advantage of the red edge**. Red is subtracted from the NIR due to NIR having a peak in brightness (higher DNs).

For NDVI and all normalised difference indices, the key part of the recipe is that it is a two-band difference image normalised by the sum of the same two bands.

1. **Describe the design and functionality of Landsat’s TM or ETM+ iron oxide and hydrated mineral (inc. clay & gypsum) indices.**

**P. 27 & 28 Lecture 2**

* Landsat **TM** detects **VNIR** (visible and near infrared), **SWIR** and **LWIR**
* Landsat **ETM+** detects **VNIR** (visible and near infrared), **SWIR** and **LWIR**

**Iron Oxide Index**:

* Iron-oxides (red/brown soils) have a high reflectance in Red and high absorption in Blue. We can enhance iron-oxides using the ratio between red (TM3) and blue (TM1) spectral bands:

**Hydrated Minerals Index**:

* Hydrated minerals have strong reflectance in SWIR1 (TM5) and strong absorption in SWIR2 (TM7). Therefore, they can be enhanced with a ratio between the TM5 and TM7 bands:

For the mineral indices’ formula, the key thing here is the subtraction of the minimum DN value in that band from every individual DN value in that band. This subtraction forces the histogram value range of both bands to start at zero. So, the division between them is more representative.

1. **Using a diagram of RGB colour cube to explain the mathematic definition and physical meaning of intensity, hue and saturation.**

**P.4 Lecture 3 (see slide for colour cube!)**

1. **What are the value ranges of intensity, hue and saturation according to the RGB colour cube model of RGB-HSI transformation?**

**P.5 Lecture 3**

* **Hue** = colour spectral range: **[0, 2]** radians OR **[0, 360]** degrees
* **Saturation** = colour purity: **[0, 1]**
* **Intensity** = colour brightness (energy level): **[0, 255]**

1. **Why RGB-HSI is a useful image processing technique?**

RGB-HSI allows us to perform **Decorrelation Stretch for image spectral enhancement** (2 common methods) and **Data Fusion for sharpening image texture** (3 common methods)

The RGB-HSI and HSI-RGB transformations allow **manipulation of colour intensity, hue and**

**saturation components separately with great flexibility**.

1. **Describe the principle of decorrelation stretch (DS) with the aid of diagrams.**

**P.7 Lecture 3 (See slide for colour cube!)**

High correlation generally exists among spectral bands of all multi-spectral images. Decorrelation stretch is a method to increase image contrast by increasing the volume of the image band information in the colour cube. Increasing the volume is equivalent to stretching both the Intensity, **I** and saturation, **S** components.

If we just linear stretch the RGB bands, we just elongate the 3D cluster up the grey line. If we expand the cluster (increase the volume) by stretching the saturation, we lower the correlation.

1. **Describe the major steps of HSIDS (HSI based Decorrelation Stretch) and explain how the image inter-band correlation is reduced and why.**

**P.8-10 Lecture 3**

**Steps of HSIDS:**

* Scaling/Linear Stretching/Clipping
* RGB-HIS transformation
* **Saturation component stretching**
* HIS-RGB transformation

HSIDS enhances the colour saturation of a colour composite image, improving visual quality without significant distortion of the image spectral characteristics. By Stretching the Image in RGB and then stretching the saturation component in HSI, the **colour separation is enhanced**, making the bands **less correlated**.

HSIDS technique enhances image colour saturation without altering the hues of the colours.

1. **What is the drawback of stretching the hue component in the HSI decorrelation stretch? How can we expand the value range of the hue component without stretching the hue component directly?**

**P.8 Lecture 3**

Stretching the Hue in HSI coordinates may **change the spectral properties of the image** when the inverse transform back to RGB is applied – the colours of the image may be different to the original image.

Achieving a wider range of H via a linear stretch maximises the spectral information shown in H (rather than in S or I). This is better than achieving a wider H range by stretching the H component itself.

1. **Using a diagram to explain the principle of DDS. In what senses are DDS and HSI DS are similar, and different?**

**P.11-15 Lecture 3 (see P.11 & P12 for DDS diagram)**

Direct Decorrelation Stretch (**DDS**) Performs a saturation stretch **without using RGB-HSI and HSI-RGB transformations**. DDS achieves the same effect as the HSIDS but involves only simple arithmetic operations (faster) and can be controlled quantitatively.

Like HSIDS, the bands must be well stretched i.e. **linear stretch before** applying DDS.

1. How to improve the spatial resolution of a 30m resolution TM colour composite with a 10m resolution SPOT panchromatic image using RGB-HSI transformation and Brovey transform?

**P.17-22 Lecture 3**

**RGB-HSI Transformation (HSI Fusion):**

* Geo- or co-reference a low- and a high-resolution image of the same area (e.g. Landsat 30 m with a SPOT panchromatic 10 m)
* RGB-HSI transformation on the **low-res colour** **composite image** (i.e. Landsat 30 m)
* **Replace low-res Intensity, Ilow component with high-res image Intensity Ihigh**
* HSI-RGB transformation for display

The **fused**/**pan-sharpened** image is a mixture of low-res spectral information and high-res spatial and textural information. Overall resolution is apparently improved but **colour distortion is introduced**.

**Brovey Transformation:**

* Brovey transformation achieves the ~ same result as HSI fusion but without any RGB-HIS / HIS-RGB transformations and so it is simpler and faster. However, it also **introduces colour distortion**.

**Data fusion improves spatial resolution via intensity, I replacement.**

1. **Explain the major problem of image fusion using RGB-HSI transformation and Brovey transform.**

**P.23 Lecture 3**

Both methods introduce **colour distortion** which modifies the original spectral properties of the image leading to unreliable image interpretation.

The colour distortion is only avoided if colour composites that use consecutive spectral bands which occupy the same spectral range as the panchromatic band are used for the fusion.

1. **How does SFIM achieve pan-sharpening which preserves spectral properties?**

**P.24, 25 & 26 Lecture 3**

**SFIM is ~ a low-res image being directly modulated by a high-res image**. The resulting image is independent of the contrast and spectral variation of the higher resolution image.

SFIM method multiplies the high and low-res images and divides by the image mean (over a local neighbourhood (convolving using a kernel)). The ratio between the high-res image and the Image mean cancels the spectral and topological contrast of the high-res image but retains the high-res textures.

**SFIM preserves the image spectral properties**. However, SFIM is more sensitive to image co-registration accuracy than the HIS and Brovey transforms.

1. **Which statement about image geometric distortion below is incorrect?**

**P. 78 & 79 Lecture 1**

1. ***Geometric distortion caused by earth curvature is unavoidable to all satellite images****.* ***True***

**All remote sensing images are subject to some form of geometric distortions**, caused by one or more of the following:

* Perspective of the sensor optics
* Motion of the scanning system
* 3D stability of the platform
* Platform altitude, attitude, and velocity
* Terrain relief
* **Curvature and rotation (produces a skew effect in the image) of the Earth**

1. ***Airborne remote sensing is not subject to the geometric distortion resulted from earth’s rotation****.* ***True***

Airborne sensing is subject to less distortion due to earth’s rotation as it is closer to the Earth.

1. ***Push-broom scanning introduces less geometric distortion than across-track scanning****.* ***True***

For an across-track two-way scanner, the distortion pattern is even more complex as every pixel along a swath is imaged at a slightly different time and the actual scanning speed on the earth surface changes not only from nadir to the edge of a swath but also between swathes for and against earth rotation.

1. *For across-track scanners, one-way scanning introduces more geometric distortion than two-way scanning.* ***False***

The distortion in the pixels occurs only in one direction not both. Therefore ~ less distortion in one-way scanning.

***Solution***

* The answers for (A), (B) and (C) are all true (to some extent).
* **(A)** All remotely sensed images from a moving platform above a moving Earth are subject to curvature distortions.
* **(B)** Airborne sensing is subject to less Earth rotation distortion than a satellite, since it is closer to the Earth and its flight direction could be co-aligned with the Earth rotation, but it is always present to some degree.
* **(C)** Push-broom scanners are subject to fewer distortions than line scanners, since an entire line is imaged at the same time, rather than pixel by pixel as with a whisk-broom, and this is why all modern passive sensors involve a push-broom mechanism.

1. **In conducting a time-series analysis/assessment of land cover and environmental condition, using multispectral imagery. Write a list of the top 5 causes of erroneous and/or unexpected results.**

**(Think of issues faced when completing group assignment of Nagasaki)**

* Cloud Cover
* Mixing up spectral bands which can lead to incorrect indices such as NDVI
* Incorrect scaling between images of the same area but at different times

***Solution:***

Improper/conflicting input data range/scaling, clouds as a separate class, clouds skewing input data range, statistical constraint by specifying too few classes, insufficient input datasets, incorrect input spectral bands, variable/inconsistent atmospheric correction amongst datasets, unpredictable feature change occurring within the time-series.