Volume XXIV 2021
ISSUE no.2
MBNA Publishing House Constanta 2021

Scientific Bulletin of Naval Academy

SBNA PAPER • OPEN ACCESS

Is it possible to use spectral signatures of materials in the visible and near-infrared range to identify real targets?

To cite this article: E. A. Ivanovich, M. Lotfizad, I. C. Scurtu, Scientific Bulletin of Naval Academy, Vol. XXIV 2021, pg.89-100.

Submitted: 10.01.2022
Revised: 24.02.2022
Accepted: 02.03.2022

Available online at www.anmb.ro

ISSN: 2392-8956; ISSN-L: 1454-864X

doi: 10.21279/1454-864X-21-I2-008

Is it possible to use spectral signatures of materials in the visible and near-infrared range to identify real targets?

Epikhin Aleksey Ivanovich [1], Mohammad Lotfizad [2], Ionut Cristian Scurtu[3]

[1] Admiral F. F. Ushakov State Maritime University, Russia
[2] Iran, Tehran, Ghods City, 313 Monir laser and optical system design
[3] Mircea cel Batran Naval Academy, Constanta, Romania

- Coresponding author email: Moben199111@gmail.com

Abstract. Using existing methods to identify and find goals in different fields, the method of using spectral signatures of materials in naval domain is important because of the more precision and fingerprinting properties of each material. If we have a spectral signature for a specific purpose, we will be able to easily identify it. However, when a material is combined at a significant level with another material, or so close that the emission and reflection of light reaches the sensor, we need spectral separation and spectral signature extraction of the combined materials. In this paper, we introduce two methods for distinguishing and identifying the signing of the spectrum of ambiguous goals that are combined with the specified materials in laboratorial environment. In these methods, by forming a matrix of data in the text of the sensor, we take the addition and subtraction operations on the data and eventually identify the target spectrum of the unknown. The first method is to deduct the spectrum of materials from the compound composition spectrum and the second method to combine the spectrum of the goals with the specified target spectrum. The method is similar to solving a first-order equation with an unknown one.

Keywords. Spectral signature, fingerprinting, naval, emission and reflection light, spectral resolution, spectrum fraction, spectrum integration.

1. Introduction

Among the methods of target detection using electromagnetic waves reflected and emitted from terrestrial terrain, the method of using the active system (especially laser active systems) in many applications and applications such as repair and testing, serious disadvantages. As a threat to health and security in the region [1]. However, in the methods that use the passive system (using sunlight and sky) to identify the effects and purposes, there are no disadvantages and threats of the active method and can be used in several bands of the electromagnetic wave spectrum (atmospheric windows). Identified goals. Of course, using the passive method also has disadvantages such as inefficiency at night and in the shade or not recognizing hidden targets (under the roof) [2-3]. As shown in Figure 1, of all the atmospheric windows, the visible spectrum (visible light) is of great use because it has no special cost and risk and is the largest transit point for sunlight.

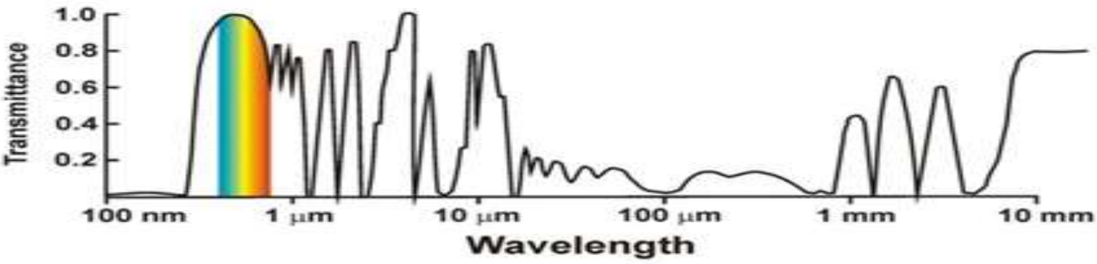

Figure 1. Most sunlight passes in the visible range.

According to Figure 1, it is possible to understand why the atmospheric window in the visible range is suitable for the passive method. Wavelengths in this range, unlike other ranges, have very low absorption and can pass through the atmosphere. In the discussion of goal recognition, we face several issues; The first problem is to find a suspicious or unknown complication that we encounter during observation or detection operations, and methods should be used to differentiate the color and temperature of the effects with the background of the image [4], the second problem after Finding an unknown complication or goal is identifying and understanding its structure and other characteristics. The process of identifying and analyzing targets can also be done by various methods such as temperature changes, using spectral signatures of materials [5], checking the geometric and visual shape, using lidars and various image processing methods, etc. Dad. Among the methods we have mentioned, the method of using spectral signature is based on the fact that each substance, according to its structure and temperature, results in a specific spectrum of reflection or emission of light, which no substance The other does not have that spectrum and is limited to one substance and is referred to as the spectral signature of that substance. This method of substance detection is used in many first-level subjects of research and military centers (as a new defense) of countries. The applications of this method are significant in civilian issues (mining, agriculture, materials, etc.) and in military issues in remote sensing of explosives [6], detection of military targets [4-5] and camouflage [7-8]. It has applications. The easiest way to check a target is to match the received spectrum with the reference library spectrum, which is registered and archived by reputable centers such as NASA; One of these libraries is (ASTER → USGS + JPL + JHU) which is a large and complete source of 2000 patterns of reflection spectrum of materials, such as minerals, rocks, soils, human materials. Figure 2 shows an example of matching a specific material spectrum with its library spectrum[9].

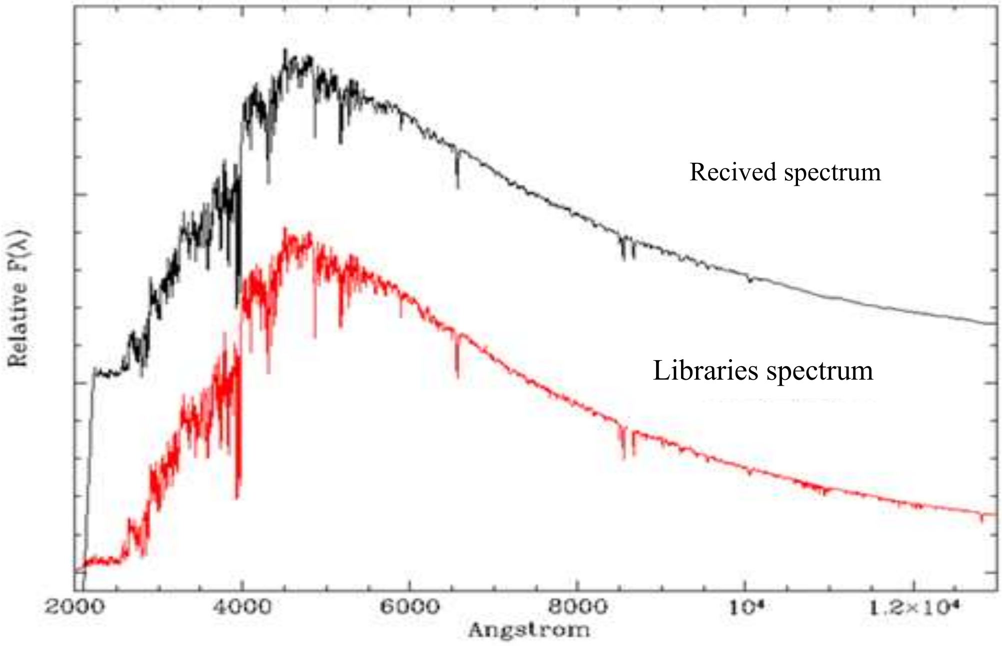

Figure 2. An example of a reflectance spectrum with the spectrum of the same material called from the spectrum library.

Here we introduce two methods that have been able to have significant results in the laboratory environment and perhaps by improving its optical system can be used in the environment outside the laboratory and at long distances. The methods presented are as follows.

Method 1: Subtract the spectra of several specific substances from the spectrum of combining the same substances with the unknown substance (target).

Method 2: Combining the target spectrum with the specific material spectra.

2. Spectral signature collection (spectroscopy)

There are several methods of collecting spectral signatures of materials depending on the type of material and how to access it (field or case) and the tools used (type of sensor, model, number of bands and spectral details of the spectrometer). Spectroscopy is one of the most widely used methods in recording spectral signatures, and in many cases, data are recorded and analyzed digitally using semiconductor and silicon sensors. To achieve a pure spectral signature of a sample, spectroscopy should be performed in the laboratory in a controlled environment and conditions (for example, in a clean room). Figure 2 shows the laboratory spectroscopy arrangement.

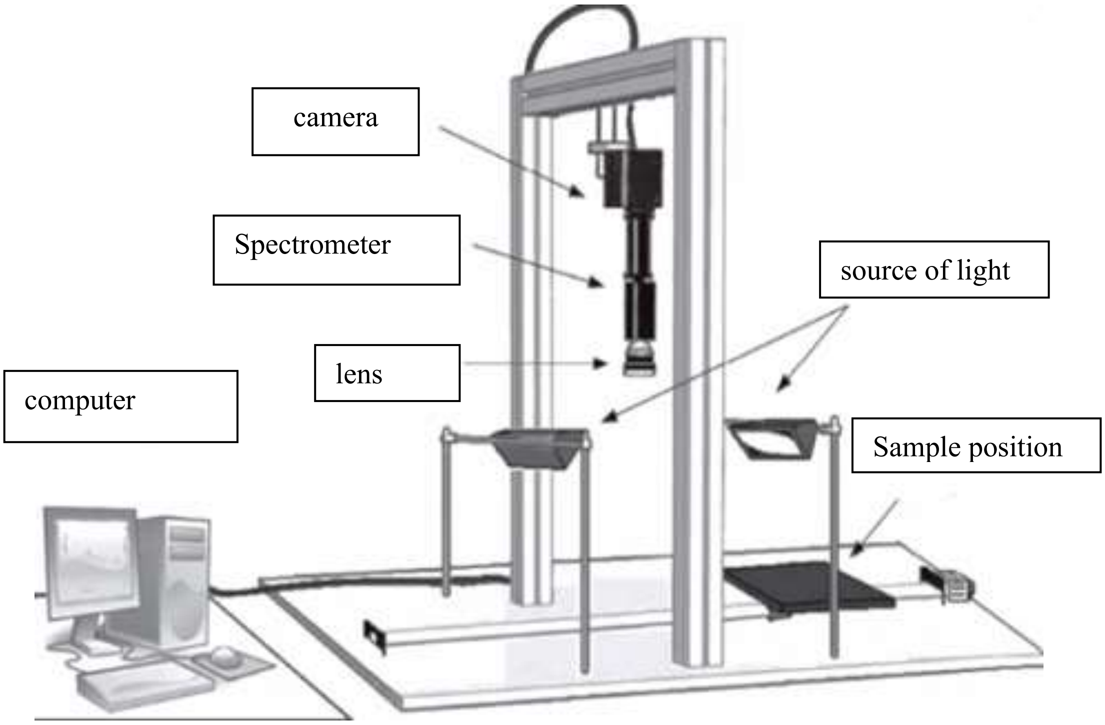

Figure 3. Schematic of laboratory spectroscopy.

For the spectroscopy of the six samples of the materials we see in Figure 4 (a-soil, b-sand, c-grass-sand composition on a red background, d-soil-sand composition, e-broadleaf, and f- Soil and grass composition), first in the laboratory environment in conditions that are somewhat under control (in terms of light and temperature), we place the samples on the desktop.

Figure 4. Materials used in the laboratory for spectroscopy; a- soil, b- sand, c- composition of grass and sand on red background, d- combination of soil and sand, e- broadleaf, f- combination of soil and grass.

Next, align and fix the input of the spectrometer system at a fixed height (depending on the field of view of the system. Here the height is 50 cm) and perpendicular to the table. We also place a light source close to sunlight (such as a tungsten lamp) perpendicular to the spectrometer input fiber so that direct light from the spectrum cannot enter the spectrometer. We use a near-visible and near-infrared spectrometer here. Figure 5 shows how the samples and tools used in the laboratory are placed.

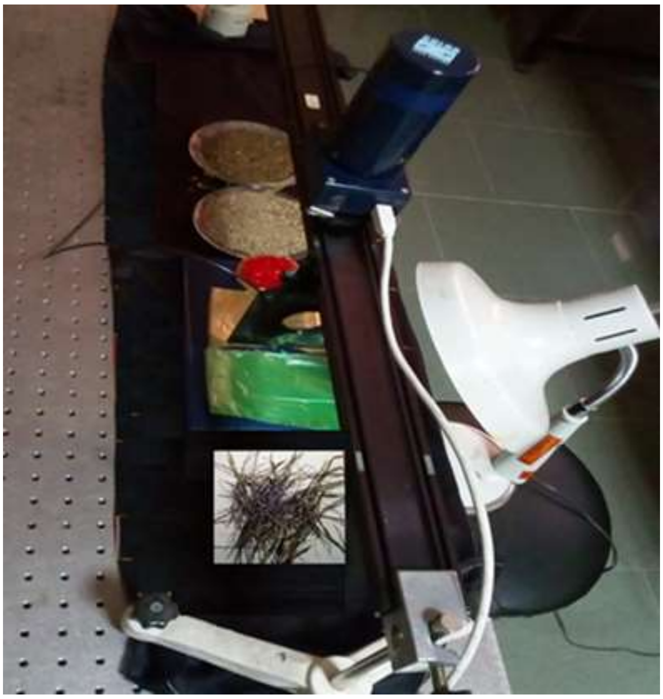

Figure 5. How to place the samples and tools used in the laboratory.

Finally from each of the materials as well as from their combinations (as shown in Figure 4) (repeat the spectroscopy several times to reduce the error). The data of the spectrometer system are in the form of spectral curve, digital (binary) and text. In Figure 6 we see the data as spectral curves for the examples.

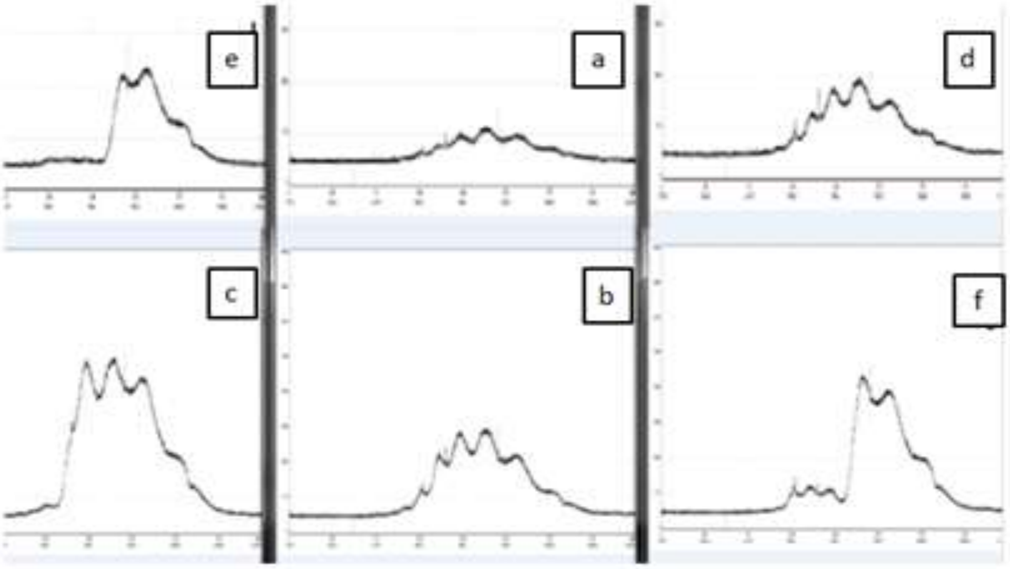

Figure 6. Data in the form of spectral curves for the sample in Figure 4.

Our goal is to use Textual data is used to separate the target spectrum from the mixed spectrum of materials. If we look at Figures 4 and 6, we see that for example there is no range of grass samples. Here we are going to get the spectral signature of the grass using spectral separation.

In Section 1, we describe two methods for spectral separation. As an example of the first method (spectral fraction); In Figure 6, to obtain the grass spectrum, we subtract the number 1 spectrum from the number 6 spectrum. This method is similar to solving a quadratic equation.

3. Predefined paragraph styles

The process of identifying the target using spectral signature, including steps; Correction of errors formed by the atmosphere [10], spectroscopy, data processing by software and the use of spectral signatures are obtained. In Section 2, we describe how spectroscopy is performed. Next, we arrange the data in text as a matrix in Excel software. A matrix whose first column contains 1000 wavelengths (from 180 to 1180) and the other columns contain the same number of numbers for the intensities of the first column of the samples in Figure 4. Next we need to use a program that recognizes textual data as a matrix and performs matrix addition and subtraction operations on the data, as well as output as a spectral curve. In this article, we use Matlab software for this purpose. In this software, the matrix formed in Excel is called and from the formed matrix, the result of text data in MATLAB output can be drawn using the plot command. The result of this process will be the spectral signature of real and unknown targets within the visible and near-infrared spectrum (in laboratory dimensions).

3.1. Data deduction method

According to Figures 4 and 6, the following equations can be deduced from a sample in the laboratory:

$$\text{grass} = f-a$$

$$d-a = b$$

$$d-b = a$$

$$c-b-rg = f-a$$

$$c-rg-f-a = b$$

In these relations, rg stands for red background. To record the spectral signature resulting from spectral separation using the data subtraction method, each of the above relationships can be investigated and proved. As we mentioned in Section 2, this method is like solving a quadratic equation with an unknown. Instead of just numbers, we use known spectra, and after solving the equation, the result will be unknown spectra. This method is basically the addition and subtraction of matrices in matlab software and the result is a spectral curve. For example, in this paper we use the relation c-b-rg = f-a to find the grass spectral signature. According to Figure 4, both sides of this relationship must have the same result. Figure 7 shows the spectral curve obtained from Matlab software for example f.

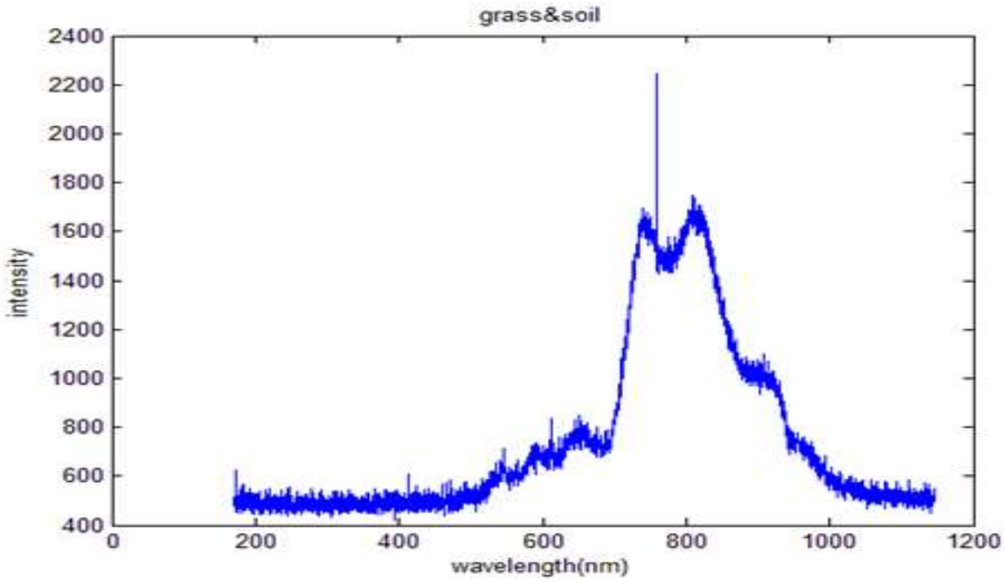

Figure 7. The spectrum obtained from Matlab software for example f.

This spectrum shows the amount of light absorption by the soil and the amount of light reflection by the grass combined at the surface of the sample f in the visible and infrared range.
After separating spectrum a from spectrum f, we have obtained the result separately in Figure 8.

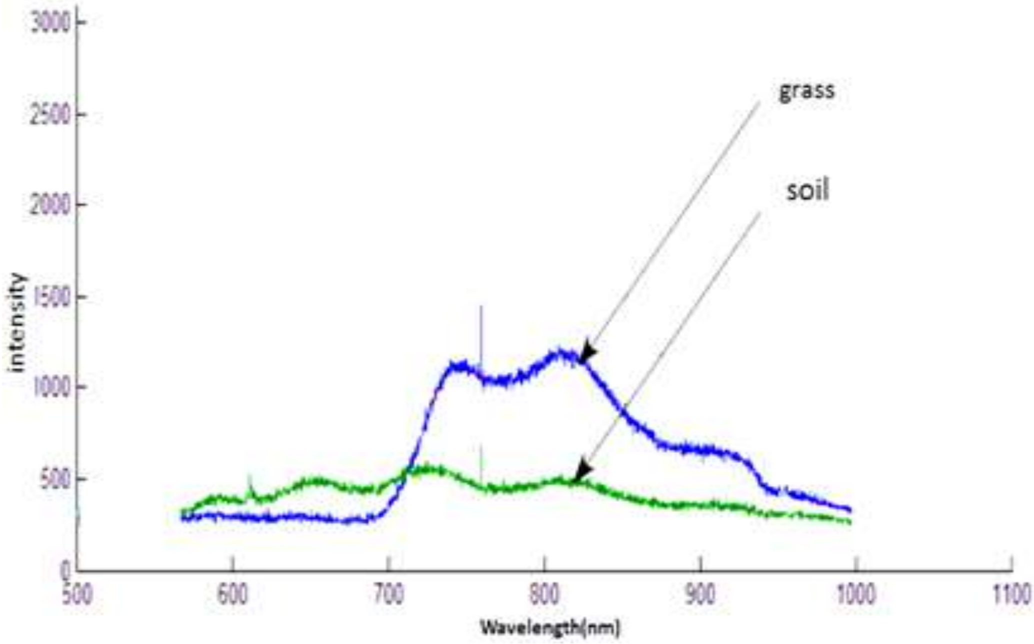

Figure 8. Soil and grass spectra separated from the spectrum curve f.

In this figure, the range of grass samples is pure, separated and recordable. Now in Figure 9 for the other side of the above relation, for example c, the spectrum obtained from Matlab software is given.

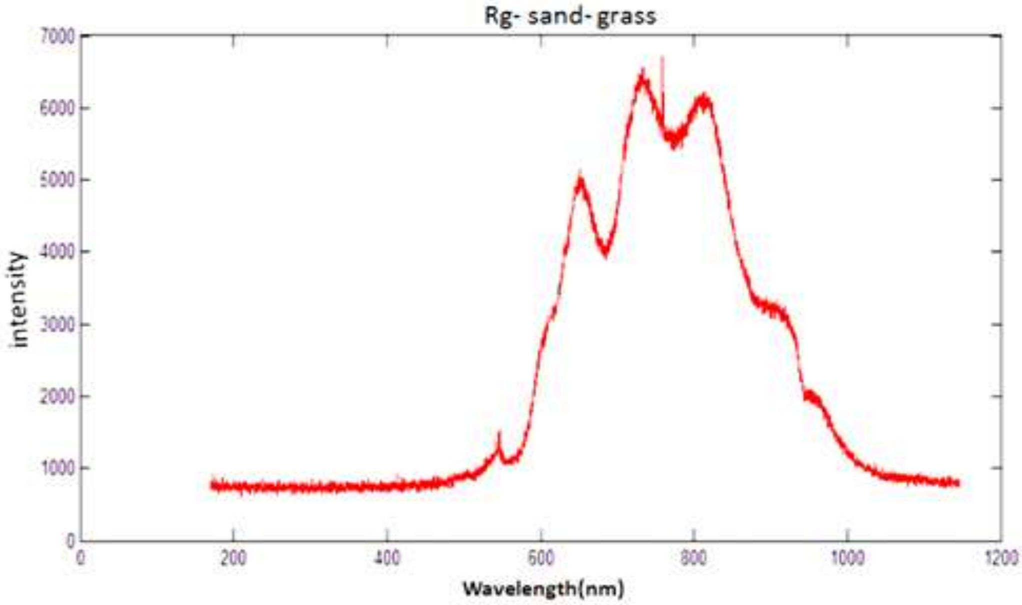

Figure 9. The spectrum obtained from Matlab software for example c.

After separating sample b as well as the red background spectrum (rg), we bring them all to Figure 9. From the two figures 8 and 10, each of which has a separate spectrum of grass resulting from spectral separation, it can be easily observed the adaptation of the spectral curve of the grass. Finally, the spectrum obtained from the data deduction method can be studied and analyzed with a spectral library to determine the type and structure of the material. As we can see, the grass spectra in Figures 8 and 10 are somewhat consistent with the sample spectrum e, which belongs to a particular tree for a broad green leaf (because they belong to the green plant family).

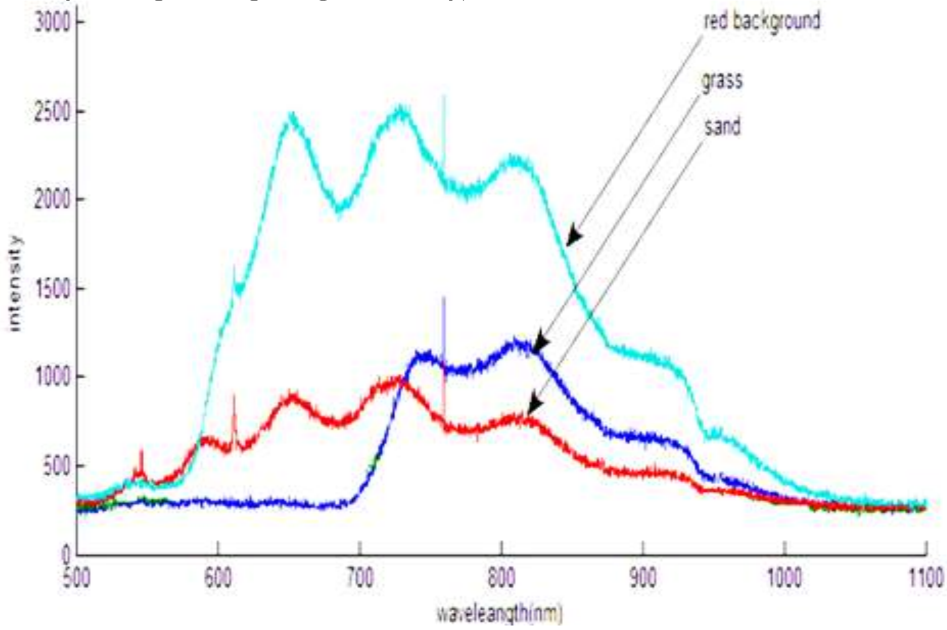

Figure 10. Sand, grass and red background spectra separated by spectral curves c.

This method of detecting the unknown spectrum also refers to the user's ability and experience to find the source of an unknown spectrum. For use in the field of military surveillance, a comprehensive plan of these steps should be written to perform this process more quickly and accurately.

3.2. Data integration method

The method of combining the unknown spectrum with the known spectra also has a step and process similar to the data subtraction method, but instead of subtracting the matrix in Matlab software, we must use the matrix sum to make the result similar to the spectrum known to us. . In this method, the process is similar to solving a first-order equation with an unknown. That is, we combine the unknown spectrum with the spectra we know to see if we can find the result in a spectrum library; Or the user is able to distinguish the composition of the spectrum according to his experience or not. For this method, we infer the following relations from the examples in Figure 4.

$$a + b = d$$

$$a + grass = f$$

$$grass + b + rg = c$$

Each of the above relations can be used to prove the method of data integration. We assume that the sample spectrum b (sand) is unknown to us, so that we do not have a similar spectrum in the library and the user is able It does not recognize it. As a result, we use the relation a + b = d to identify the type and structure of the unknown spectrum. Figure 11 shows the unknown spectrum b as the output of the spectrometer system.

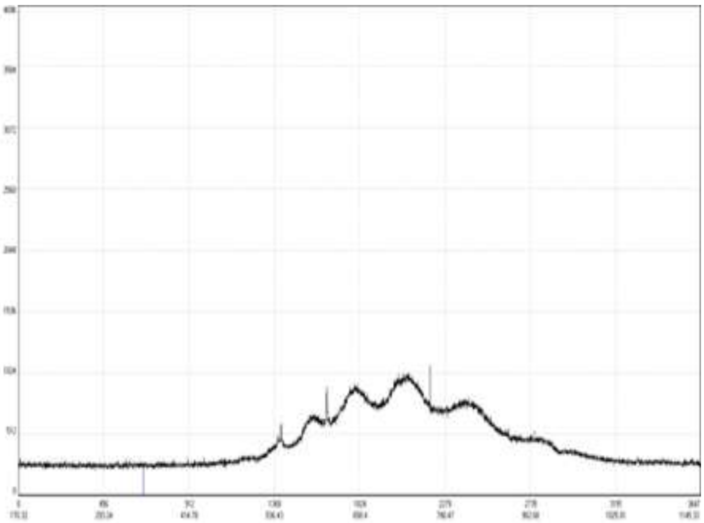

Figure 11. Unknown spectrum b as output from the spectrometer system.

After recording the unknown spectrum, we perform the steps given in section 3 for the text data of this example. The result obtained From Matlab software to combine this unknown sample with sample a is shown in Figure 12. With a little care one can see how similar the result is to the sample range d (due to compression, some value is drawn in the direction of intensity). If we already have information about the sample spectrum d in the spectrum library, we can specify the constituent spectra.

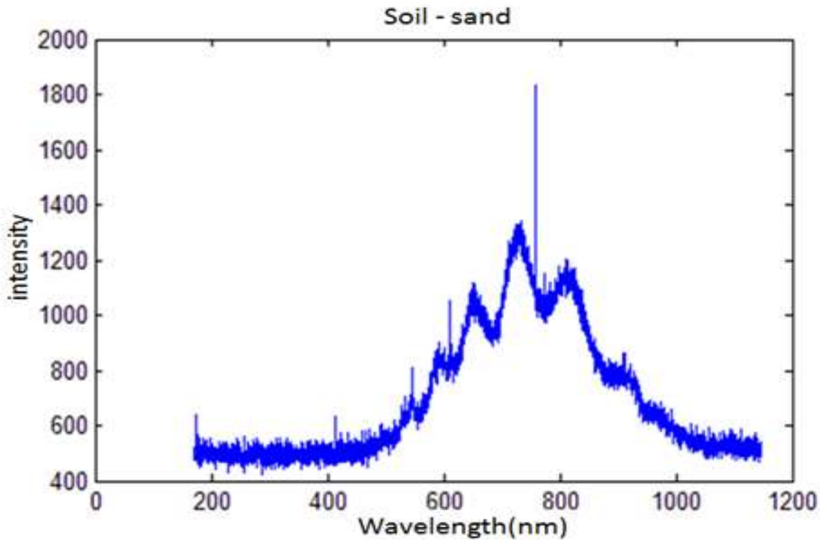

Figure 12. The result obtained from Matlab software for combining soil and unknown spectrum.

With this trick, the initial spectra of this compound can be easily identified. Here, after examining the spectra of Figure 12, and comparing it with the sample d in Figure 4, we conclude that the unknown spectrum belongs to the sand spectrum. Then, using the spectral separation described in the previous section, we first subtract the unknown spectrum we guessed (example b) from the general spectrum (example d); If we reach a spectrum that we have added to the unknown spectrum, the conclusion is completely correct and the spectra can be recorded and stored as the signature of the unknown target spectrum. Figure 13 shows the results of this method and their separation.

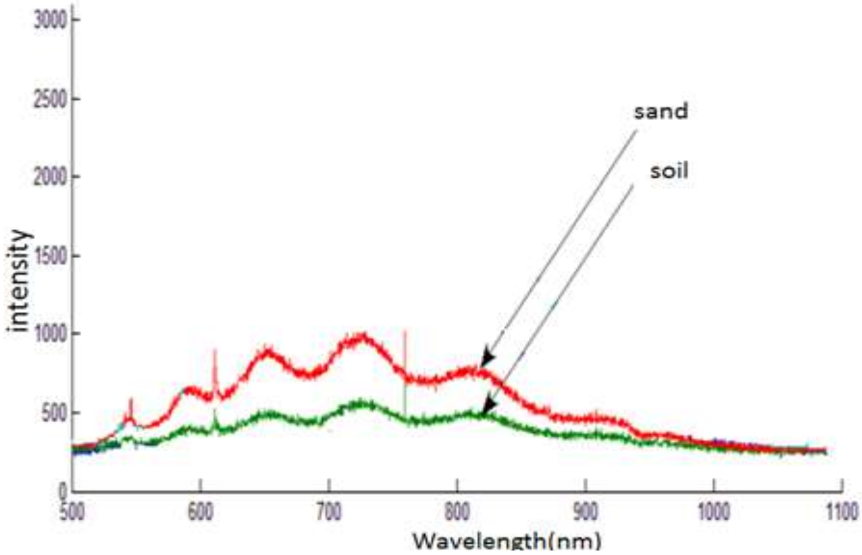

Figure 13. The result of spectral separation by data integration method.

As shown in Figure 13, after performing the data integration method process, the source of the unknown spectrum can be easily identified. Here, the obtained spectrum is consistent with the high percentage of spectrum b, which is for sand. In this paper Epikhin Aleksey Ivanovich and Ionut Cristian Scurtu contributed with numerous proofreadings and editing and synthetized the current article from Mohammad Lotfizad research outputs.

4. Conclusion

In this paper, we were able to use spectral separation to identify the spectral signatures of several unknown substances that were combined with potential naval application, and again to use the same spectral signature to separate other unknown spectra step by step. The procedure is like solving a first-order equation with an unknown. Spectral separation can be done by two methods of data subtraction and data integration method. In the data subtraction method, we subtract the known spectra from the composite material spectrum to arrive at the unknown spectrum. In the data integration method, we add the unknown spectrum to several separate or multiple spectra so that the resulting spectrum is recognizable to us. Then, by examining the spectra participating in the final spectrum that we know, we can also identify the source of the unknown spectrum. For monitoring purposes in any field, several softwares and programs are required, including; Provide what we have stated in this article to discover and identify goals more quickly and accurately. By equipping the focal system, this method can also be used for slightly farther (a few meters) purposes.

References

[1] Cech, V., & Jevicky, J. (2009, September). Simulation of Target Range Measurement Process by Passive Optoelectronic Rangefinder. In 2009 International Conference on Computational Intelligence, Modelling and Simulation (pp. 181-186). IEEE.

[2] Khazaei, S., Homayooni, S., & Safari, A. R. (2010). Hyperspectral Imagery and CC&D Considerations Against its Threats. J. Adv. Defence Sci. & Tech, 2, 63-74.

[3] Khazai, S. "Fundamentals of Remote Sensing with a View to Identifying and Care"; Imam Hossein University, 2009.

[4] Kohl, A., Cochran, J., & Cropek, D. M. (2010). Characterization of military fog oil by comprehensive two-dimensional gas chromatography. Journal of Chromatography A, 1217(4), 550-557.

[5] Luft, L., Neumann, C., Freude, M., Blaum, N., & Jeltsch, F. (2014). Hyperspectral modeling of ecological indicators–A new approach for monitoring former military training areas. Ecological indicators, 46, 264-285.

[6] Weatherall, J. C., Barber, J., & Smith, B. T. (2016). Spectral signatures for identifying explosives with wideband millimeter-wave illumination. IEEE Transactions on Microwave Theory and Techniques, 64(3), 999-1005.

[7] Sedaghat, A.; Dehghani, H. "An Efficient Camouflage Assessment Approach for Remote Sensing Images"; J. Advanced Defence Sci. & Tech. 2011; 4, 295-306 (In Persian)

[8] Zavvartorbati, A., DEHGHANI, H., & JABBAR, R. A. (2016). Effectiveness assessment of camouflage designs based on spectral anomaly feature.

[9] Baldridge, A. M., Hook, S. J., Grove, C. I., & Rivera, G. (2009). The ASTER spectral library version 2.0. Remote Sensing of Environment, 113(4), 711-715.

[10] Baquero, E. H. Survey of Advanced Technologies in Imaging Science for Remote Sensing.;U.S. Air Force Academy , Rochester Institute of Technology, 1997.

[11] Mohammed, Z. (2021). The Effect of the Fiber Bragg Grating model; Index modulation on the Spectral Characteristics of Fiber Bragg Grating. Technium: Romanian Journal of Applied Sciences and Technology, 3(1), 167–177.

[12] AL-Assadi, Z. I., Asadi, F., & Alameri, B. M. (2021). Eliminate obstacles of use the solar systems as buildings facades using multilayers optical interference filters. Technium: Romanian Journal of Applied Sciences and Technology, 3(8), 83–91. https://doi.org/10.47577/technium.v3i8.4829

[13] Fohoue-Tchendjou, K. ., Kamla, V. C., & Bitjoka, L. (2020). Management of Hybrid Renewable Energy Systems Using Differential Hybrid Petri Nets. Technium: Romanian Journal of Applied Sciences and Technology, 2(7), 64–76. https://doi.org/10.47577/technium.v2i7.1616