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# A Study on Thermography

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**Abstract—** Thermography has become an intensive domain of research. Initially it was introduced in military to be able to see threats in dark areas in early twenty century. In 1948 it took 40 minutes to scan a thermal image of a person. Since then technology has evolved rapidly. The vast range of its application makes the technology so appealing to the researchers. It is used as an inspection tool in industries as well as in major science discoveries. For lack of appropriate experimental results it is not yet considered to be a trusted tool in medical science. Major issue of this technology is its expensiveness. This paper mainly focuses on the applications of this technology, its effectiveness on the respective domains and some research, experiments and their results.

**Keywords—** DITI; Infra red; Thermal imaging; Industrial Inspection; Breast cancer diagnosis; Thermal screening; Space research; Heat signature ;Emmisivity.

## I. INTRODUCTION

Thermography is the study of capturing Thermal imaging or Infrared imaging. According to Black Body Radiation law any matter with a temperature above absolute zero emits infrared radiation. A thermal imaging camera can detect the infrared radiations of matters. As the temperature of the surface of an object increases, the thermal radiation and thus the infrared radiation also increases. Therefore in a thermal image worm or hot objects are visually more prominent than the cooler ones. It is also possible to obtain temperature measurements of the surfaces of objects in a thermal image. Different colors in the image can mean different temperature. Principally dark areas cooler and bright areas are hotter. A conventional term for this is Digital Infra-red Thermal Imaging (DITI).

***Fig. 1. Thermal Image.***

The major domains where the technology truly dominates are Thermographic inspection in both industries and regular household maintenance and space research. Other than these thermal imaging are advised and often applied are medical diagnosis, military usage, search and rescue, detective investigation etc. The rest of our discussion mainly focuses on the efficacy of Thermography in those domains. Before that one thing needs to be cleared that Thermography is not night vision. Night vision amplifies the ambient light whereas Thermography takes infra-red measurement. Night vision does not work in absolute absence of light but Thermography does, since it does not capture visible light.

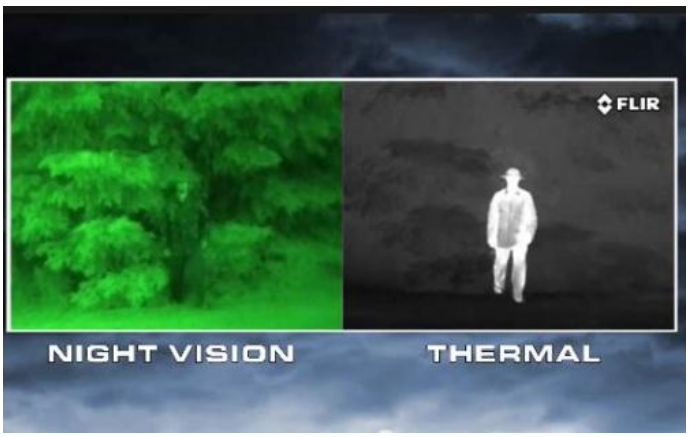



*Fig. 2. Night Vision VS Thermal Image*

## II. THERMAL OR INFRA-RED INSPECTION

The biggest benefit of thermal imaging is that it does not require contact and infra-red radiation can be captured from far apart from the object. In industries where huge metallic devices run constantly, temperature increase and decrease is evident in various places. It is impossible to measure those temperature differences to find a leak or a damaged metal insulation. The engineers use thermal cameras to scan the device from temperature measurements. If any part of the device has unusual temperature reading then respective technicians can look deep into the problem. For same reason infra-red imaging is done in electrical circuits to find defects. One of the worst thing that happens in industries is fire generated from electric sparks. Without the help of infra-red imaging, electric grids need to be checked and verified manually. Plus an active device in run time may behave different from when it is at rest. Fig.3 shows a picture of electronic fuses. In abnormal situation the loosely connected fuse produces more heat since loose connection increases resistance.

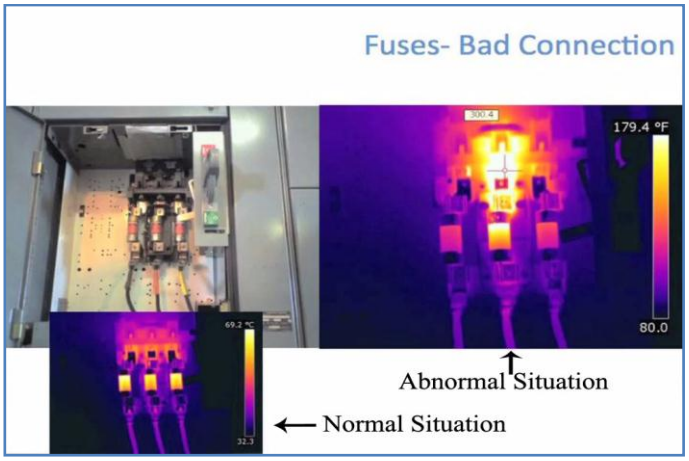



*Fig. 3. Electric fuses in loose connection.*

Thermal insulation in both regular household and industrial instruments is inspected with infra-red technology. Looking at a plain wall, one cannot determine the where exactly the damage is. Thermal images show the leaks or defects in the structure. Thus only those portions can be torn down and rebuild or repaired. Fig. 4 shows a picture of a ceiling. In the normal view the ceiling looks perfect, but the thermal image reveals that a lot of heat is coming in from the ceiling.


*Fig. 4 Normal and Thermal image of a ceiling*

Fig. 5 shows points out leaks in gas container. Also the squared area has much higher temperature than other areas. Thermography is also been proposed and applied in soil testing [20,21].

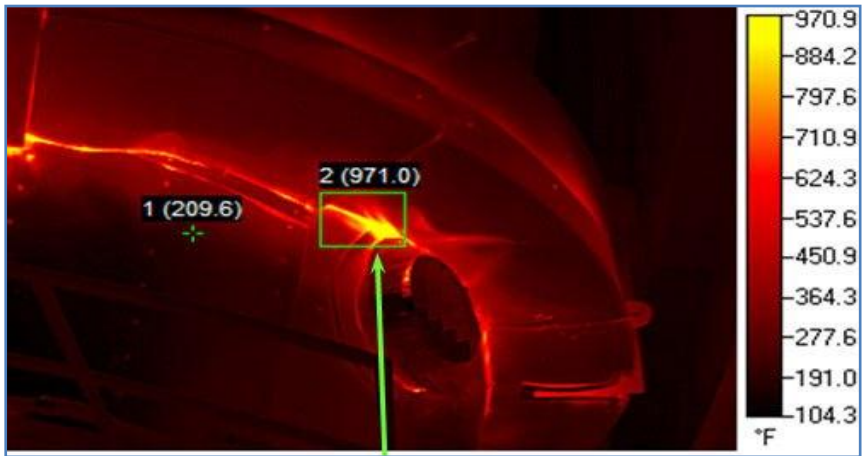



*Fig.5. Gas leaks in thermal image*

## III. THERMOGRAPHY IS SPACE RESEARCH

Infra-red imaging has turned out to be a revolutionary technology in space research over the last few decades. Thermal images of the sun, our moon, moons of other planets, astronomic events etc. has been a source of invaluable information. Scientists and researchers can measure temperatures of planets and starts that are thousands of miles away. Infra-red light has longer wavelength than visible light. Which means the stars and planets that we cannot see in visible light, in infra-red we can see them. So the sky is denser in infra-red imaging.

Infra-red observations are vital for detecting asteroids that might be a threat to the Earth. By measuring their orbits and size using infra-red telescope, and their composition using visible light, we can calculate both the likelihood of a collision and their mass, allowing us to assess the threat and come up with a solution or safety strategy before it can hit the Earth[1].

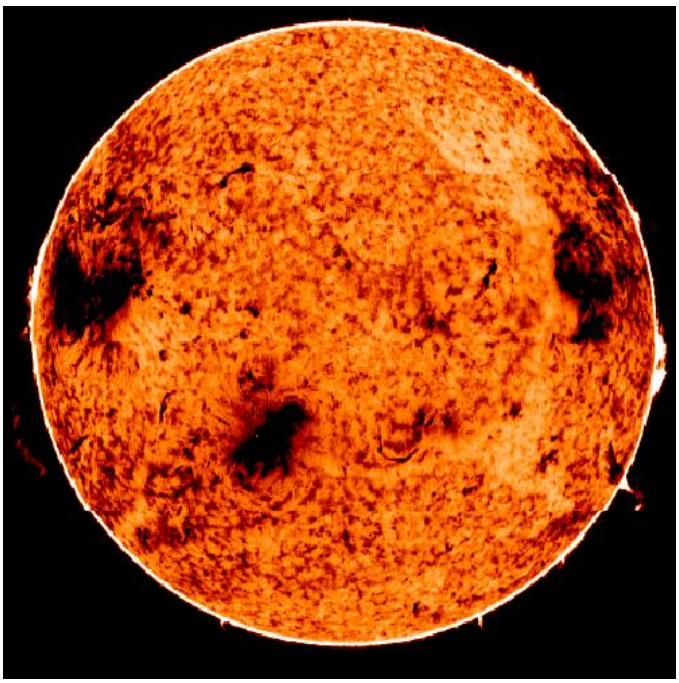


***Fig. 6 Infra-red Image of The Sun***

In 2006, Space research facility NASA used thermal imaging to find caves on Atacama Desert in Chile[2]. The aim of this project was to develop a protocol to find caves in Mars. Cave entrances are normally cooler than the surrounding rocky area. Thus thermal images can detect this temperature difference.

*Few discoveries*

- Scientists have found a way to use infra-red radiation as a new renewable energy source[3]. Their work is still in progress. The earth is hot. Therefore it has infra-red radiation. This energy can be a renewable energy source in near future. This could be even better that using solar energy since infra-red energy can be harvested 24 hours.

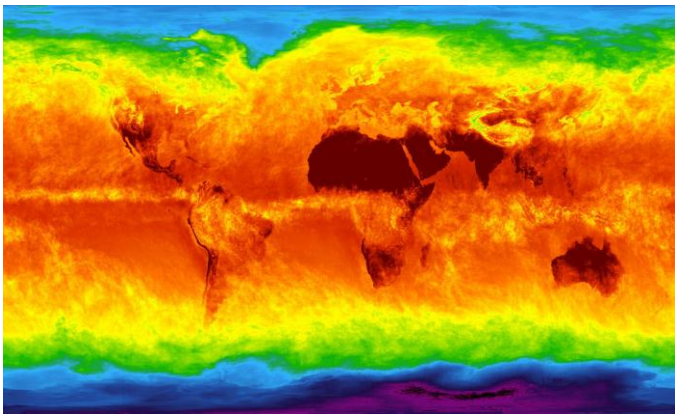


***Fig. 7 Infra-red Image of Earth***

- Infra-red imaging shows that the ammonia ice cloud of Jupiter is cooler. Infra-red observations make it possible for the scientists to follow the temperature patters on the surface of planets (e.g. The great red spot in Jupiter)[4].

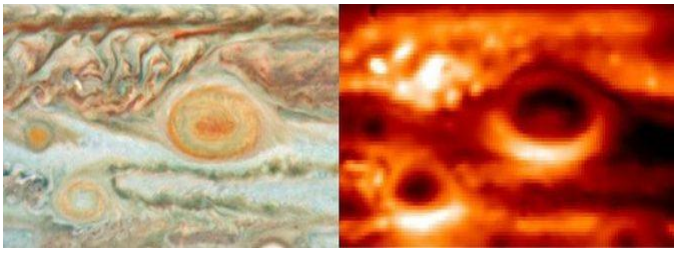


*Fig. 8 The Great Red Spot on Jupiter*

- Infrared observations allow astronomers to easily pinpoint the volcanoes that are still active on IO, the innermost moon of Jupiter, allowing them to differentiate between current and old volcanic activity[5].
- Infra-red imaging ate used to find "Brown Dwarfs". Brown Dwarfs are neither starts nor planets[6]. They are cool and dark in visible light. But they glow in infra-red light.
- Mimas is Saturn's small inner moon. It has a very strange pattern of daytime temperatures, which are being studied in the infra-red[5].

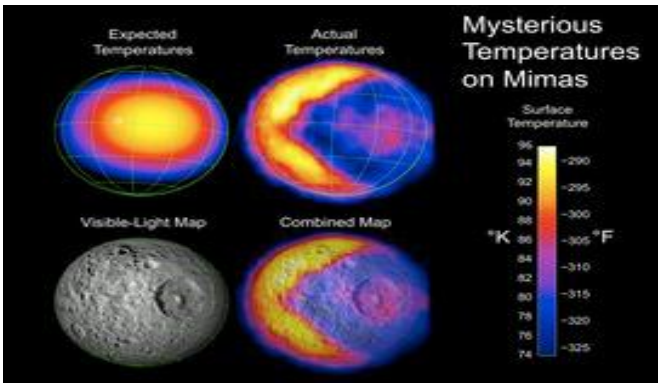



*Fig. 9 Temperature patterns of Mimas*

## IV. THERMOGRAPHY IN MEDICAL DIAGNOSIS

Capturing Infra red images of the surface of the body and digitally or manually examining the produced image to identify illness is generally termed as Thermal screening or Infra-red screening. Different regions of our body surface have different temperature. Thus a digital image generated by thermal screening will have different thermal readings. This variation has a pattern. Some regions are hotter that the other. But if an image does not follow the pattern, then the patient may be unwell. The reason this works is because damaged or ill areas are hotter than its surrounding areas.

### *A. Breast Cancer*

If cancer can be detected at early stage, it can be controlled. So far technologies like mammography and ultrasound has been affective in order to diagnose cancer. Recent studies prove that thermal imaging can also be powerful tool. The cancerous cells grow very rapidly and they have fast metabolism, also they grow new blood vessels to bring more blood, more oxygen more nutrients. Which makes the cancerous region warmer than the healthy tissues around it[7].

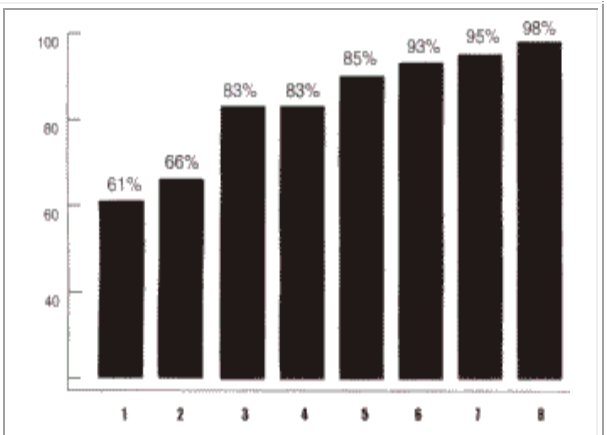
Since breast cancers are hot and they grow close to the skin surface, thermal screening is possible and the digital picture is examined to identify cancerous tissue. Although this is proposed by many researchers and medical experts, the accurateness of this approach is still a topic of intensive research. Thermography is attractive because it does not require contact and radiation exposure.

#### *1) Experiments and results:*

*a)* An experiment with 26 patients with nonpalpable breast cancer was done by Thermography. 15 patients (55%) were correctly diagnosed by Thermography at steady state, 4patients (14%) were correctly diagnosed by the aid of dynamic Thermography and 3 patients (11%) were correctly diagnosed by the aid of μ-Thermography[8].

*b)* Another trial, 92 patients for whom a breast biopsy was recommended based on prior mammogram or ultrasound underwent DITI. Three scores were generated: an overall risk score in the screening mode, a clinical score based on patient information and a third assessment by artificial neural network. Sixty of 94 biopsies were malignant and 34 were benign. DITI identified 58 of 60 malignancies, with 97% sensitivity, 44% specificity, and 82% negative predictive value depending on the mode used[9].

*c)* Based on another experiment the following graph was computed[10].




**1. Suspicious clinical exam; 2. Suspicious mammography; 3. Suspicious clinical exam or suspicious mammography; 4 Abnormal infrared imaging; 5. Suspicious or equivocal mammography; 6. Abnormal infrared imaging or suspicious mammography; 7. Abnormal infrared imaging or equivocal or suspicious mammography; 8. Abnormal infrared imaging or suspicious mammography or suspicious clinical exam.**

***Relative sensitivity of clinical exam, mammography, and infrared imaging in 100 cases of DCIS and stage I and II breast cancer***

### *B. Horse racing*

This technology is used in a Horse racing[11]. Many times in our normal life we feel small internal pain or minor cramps which we ignore. But sometimes those small things turn out to be a blunder. This happens to animals too. The difference is that we can speak our mind but they can't. So what happens is say a horse gets hurt during a race. If it is not a serious one, then most probably it will go unnoticed. Then the next time it runs again and this time the old injury develops and it gets worse. Now the owner may lose his money, he has to take care of the horse or even worse, it may not be able to run again. All this could have been avoided if only someone knew the problem when it was little.

### *C. Others*

Using infra red imaging to find damaged tissue or vain ruptures is advised by researchers. The problem in this is affordability. Thermal imaging cameras are more expensive than an enhanced laptop or a motor bike[12]. An infra-red Thermography typically costs hundreds of dollars[13]. It would be rarely the case when someone would want to spend so much to find a cramp in his leg. That being said the horse racing example fits well, simply because the business is beneficial. Infra-red imaging

has also been assessed to determine pregnancy status [14]. In Canada thermal camera is not licensed as medical device. In Fig. 10 the thermal image shows a fracture on the right ankle. Researchers are working on how to apply Thermography in microbiological testing procedures[19].

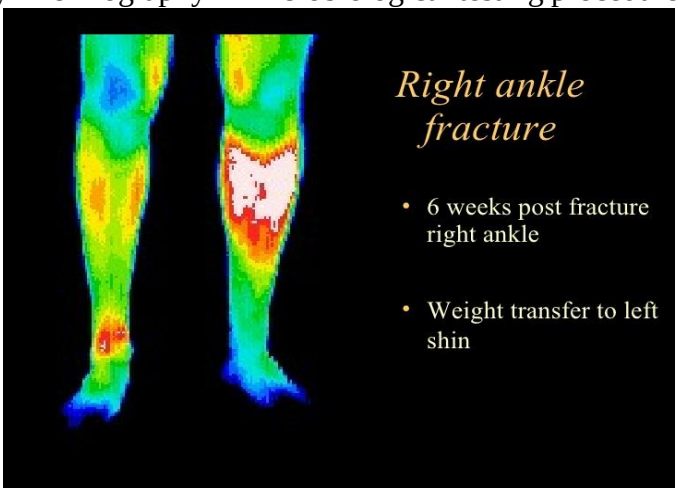



***Fig. 10 Infra-red Image of human legs***

## V. THERMOGRAPHY IN SURVEILLANCE AND MILITARY APPLICATIONS

Regular CCTV cameras are limited by it's need of light and night vision doesn't work during the day. Thermal surveillance cameras are becoming popular since they work without light and both in day and night. Military base camps or border guards use infra-red cameras to identify intruders.

***Fig. 11 Normal and Thermal Image in the dark.***

In Fig. 11 at the left side we see a dark image at night. This image is in normal camera. The infra-red image on the right shows an intruder. Recent developments have produced thermal imaging rifle scope.

Infra-red radiations can pass through smock to some degree. This is why firefighters use this technology to see if anyone is stuck inside. Hunters use this technology to spot their target in the woods.


***Fig. 12 Thermal Image in smoke***


*Fig. 13. Thermal Rifle Scope*

## VI. HEAT SIGNATURE

Every object has a heat pattern. For example, a human body has different temperatures on different surface area of the body. This variation has a pattern. Any two similar objects should have a similar heat pattern on its surface. The pattern is called Heat Signature. In military any two rockets or jets from the same manufacturer should have the same heat signature between them. A 'Heat Seeking' missile uses this heat signature to find its target without any guidance. Based on the heat signatures of aircrafts the army distinguishes between their opponent and themselves. Stealth aircrafts try to hide or reduce heat signature.

## VII. ISSUES IN THERMAL IMAGING

Two major issues of this technology are its expensiveness and accuracy. Even the cheapest and low quality Infra-red/Thermal camera is of two thousand dollars. Which is lot more money than one would like to spend for personal use. The accurateness of the temperature measurement of an object, using Thermal imaging, depends on two things, the object's Emissivity and noise due to the surrounding objects. Emissivity is the measure of an object's ability to emit infra-red energy. It ideally ranges from 0.0(shiny mirror) to 1.0(blackbody). While capturing Thermal images the camera also picks up the infra-red energies that are coming from the surrounding objects, since almost everything radiates infra-red energy.

## VIII. CONCLUSION

Infra-red energy is reflected by mirror; therefore thermal imaging of an object reflected by mirror is possible. The major advantage Thermography is we can take temperature measurements of an object while being far apart from the object physically. This is why this technology is so much popular in space research. Secondly its inessentiality from visible light makes it more attractive in military and surveillance purposes. One major problem with this technology is its affordability. It makes sense for and engineer or inspection officer to spend a few thousand dollars on an infra-red camera. But for regular people it is not reasonable. Although companies like FLIR System have been able to reduce it to a minimum of two thousand dollars (the lower model) from what was 50 thousand 5 years ego, significant decrease in cost is still needed. Once that happens anyone with a smart phone can take thermal images which will indeed make the world a safer place. Finding an explosive, spotting an intruder hiding behind the certain, finding gas leaks etc. will be much easier. Thermography is medical science does not have a big impact as of yet. The Food and Drug Administration (FDA) of USA stated that Thermography is not an alternative to Mammography[15]. Many others are also against its use in cancer diagnosis while another group of experts shows that Thermography combined with Mammography could be much more sensitive.

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