Radar Imaging Systems
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ABSTRACT
This paper looks at 3 different types of radar imaging systems; synthetic aperture radar (SAR), through-the-wall radar, and digital holographic near field radar. Each system surveyed experiments that improved the quality of the resulting image. It was found that each radar system has specific problems.

The digital holographic near field radar imaging system was studied the closest. Findings revealed that incident angles greater than ten to fifteen degrees divert the radar signal to much and do not get received. This causes data to get lost.

KEY WORDS
Radar, Holographic, Imaging, Systems

1. INTRODUCTION
Radio signals have been experimented with since the 1887 [2]. The first functioning radar systems were developed in the early 1900’s [2]. However, since the early 1970’s radar signals have received more attention from scientist and researchers [2]. This is when scientist used radar signals to start generate images [2]. The images being generated lacked resolution due to the minimal amount of computing power that was available [2]. Recent advancements in computer processing power have allowed computationally intensive approach to be implemented and tested [7].

As an applied technology, radar imaging has seen significant improvement since its inception, and new uses for radar are currently being developed [7]. Recent advances include the application of mapping objects in 3-D and seeing through walls. One significant challenge of these new applications of radar imaging is dealing with possible interference [7]. Current research is being done to identify techniques that can improve radar image clarity [7].

This paper will survey three different types of radar systems; Synthetic Aperture Radar (SAR), through-the-wall radar using ultra-wide band (UWB) radar, and digital holographic near field radar imaging. These systems will be reviewed looking at current methods, equations, and images. The general benefit of these approaches will be discussed and a possible future direction will be proposed.

2. RADAR SYSTEMS
There are many applications of radar systems in the world today. Some of the other systems that exist in radar will not be looked at because many of them can be compared to one of the three imaging systems; SAR, through-the-wall, and digital holographic near field radar. Other systems that can be categorized with these radar imaging systems are; sonar, ground-penetrating radar, Doppler, and many others [7].

Radar systems use signals to generate backscatter data. Backscatter data refers to the radar signal that is reflect back from the incident object also considered an echo. The most popular radar signals used are radio waves or microwaves, which can be classified as electromagnetic waves [2]. These signals can vary in power and band range in order to meet the demands and accuracy of the radar system.

To understand exactly how radar works one would need knowledge of the Physics field Electricity and Magnetism and Electrical Engineering. However, the basics can be explained rather simply. By timing how long it takes for a signal to return after hitting an object, it is easy to obtain distance. Since, speed of the signal is known, getting the distance of the object is basic Newtonian Physics (distance = velocity * time). However, remember to divide the time by two because, the signal travels to the object and back.

Most radar systems today do not use clocks to time how long it takes for a signal to return [7]. Instead, it uses a much more advanced technique called chirping [7]. Chirping, pulses signals very rapidly on an increasing and decreasing power scale. To better understand this process research chirp radar.
2.1 Synthetic Aperture Radar

There are several ways that SAR is used; however all methods use a moving system to study or survey a specific surface. For a SAR system to work correctly it is assumed that the radar is traveling at a constant velocity and a constant altitude parallel to the ground [6]. SAR usually uses narrow band microwaves to generate an image [5]. However, recently the impact of UWB signals has greatly increased image resolution [5]. Flyover SAR uses three different survey techniques. These techniques are called spotlighting, stripmapping, and scanning (See Figure 1) [4].

There are many advantages of using radar instead of standard fly-over photography or imaging. Radars can be used at night, can see through cloud cover, and can be more accurate [6]. To obtain higher accuracy and resolution, doing land surveys over time and taking a statistical average of the backscatter data helps [6]. Experiments also show doing statistical analysis of the data greatly reduces the noise (See Figure 2) [6]. These images were generated using the stripmapping technique and a narrow-band signal [6]. However, one negative of this method is that making multiple passes of a certain area takes time, and time is something people try to eliminate or reduce.

Spotlighting technique images can be very clear (See Figure 3). However scanning and stripmapping techniques can be noisy and unclear. There are many possible factors that can lead to resulting image being poor quality. These factors can be storms, land angles, and other reasons, that can cause a signal to not return.

2.2 Through-the-wall Radar

Through-the-wall radar system can be very useful for civil engineering, law enforcement, search and rescue, and other situations, where knowing what is in a room before entering can give you a tactical advantage [1]. This is a very new method that uses UWB signals to penetrate a standard drywall composed of gypsum [1]. Many experiments are being done to test methods for improving through-the-wall radar imaging. One new mathematical approach is applying a normal moveout (NMO) correction formula (See Figure 4) [1].

\[ T_i = \frac{2 \sqrt{h_i^2 + \left( \frac{d_i}{2} \right)^2}}{c} \]

This formula takes into account the distance relationships of the object or objects behind the wall, the transmitter, and receiver in relation to each other [1]. The setup of this experiment included many receivers along a wall using varying transmitter positions (see figure 5) [1].
Experiments were completed without using the corrective NMO calculations, and the image was greatly distorted [1]. The result of applying the NMO correction formula showed increased accuracy in depicting the object behind the wall (See Figure 6 vs. Figure 7) [1].

Improving the image even further can be done by applying statistical average of the backscatter data over time. However, in order to generate a better resulting image, there would need to be many more transmitters and receivers [1].

2.3 Digital Holographic Near Field Radar

This system is the latest in radar technology imaging. Digital Holographic Radar requires heavy calculation of several triple integrals in order to generate an image [7]. These systems are beginning to be used in airport security and custom clothing tailoring measurements [7]. Signals are transmitted using an UWB chirp scale to get accuracy down to millimeters [7]. The radar system uses a moving transmitter and receiver wand, which travels around the subject/object completely taking over a 100,000 point-distance measurements (See Figure 8) [7].

The resulting data from the scan takes approximately 25-30 seconds to render and generate an image [7]. The system uses intense mapping algorithms and integration techniques to give a smooth surface to all the data points taken [7]. The resulting image can then be measured to obtain, in-seam, thigh circumference, waist, bust, shoulders, and any other measurements a tailor would need (See Figure 9) [7].

Figure 6: no correction

Figure 7: NMO correction

Figure 9: Resulting 3D Image from Body Scanner [7]

This image that has been generated is still far from perfect. There is a lot of information missing in the arms, shoulders, neck, and head [7]. This is due to the incident angles at which the radar signals strike the body and are reflected back [7]. Studies have shown that an angle greater than 10-15 degrees relative to the particular will result in a great deal of deflection and that signal with then be lost [7].

3. DISCUSSION

All these radar imaging systems are attempting to obtain valuable data for specific situations. Each system is trying to accurately and precisely map a specific surface or object. In the SAR system exact measurements are needed for doing land surveys and reconnaissance. For through-the-wall radar it is necessary to be able to easily distinguish between a random object and a person. Each system has room for improvement due to certain factors causing missing data.

In the future radar imaging system can and may see great improvement. The development of smart mapping algorithms may be able to fill in the blanks left by missing data. Other intelligent algorithms may be able to eliminate erroneous data due to noise or other factors. Using these techniques the limitations in accuracy and precision of radars and radar imaging systems is uncertain.

4. PROPOSED WORK

Generating images from the data of radar can be extremely difficult due to missing data. Missing data occurs because the radar signal did not return back to the source or receiver. In certain applications of radar and radar imaging missing data does not cause issues. However, in 3D digital holographic radar imaging
missing data causes gaps and rigid lines, which create problems when attempting to extract measurement of the created 3D object. Further research to apply triangle meshes over the generated surface can smooth and fill in the gaps of the missing data.

The process to create triangle meshes uses the point scatter plot generated from the radar [8]. Using the scatter plot we can create inner triangles to fill the object and increase the smoothness and fill in missing data. Using series of equation triangles can be found. However it is important to check to ensure that the bounds of the triangle do not go outside of the object.

The reason why smoothing and filling in the missing areas of 3D scanned objects is because obtaining accurate measurements can be used for many applications. Looking at the 3D scan of a human, it can easily be seen that there are problems area in the arms, shoulders, and head. Using the proposed method, it is possible to smooth and fill these areas [8]. Tests will allow for us to see how accurately triangulation meshes will fill in missing data areas.

The steps necessary to research and implement this system will take approximately 8 - 10 weeks and cost $100,000. This cost will be for obtain office space, hiring help, and further research and development. The first stages will involve research current methods of creating 3D meshes from 3D scatter plots. The next stages will be to compare the finding to see which method works the best. The final stages involve implementing the best method to the current 3D digital holographic radar system.

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<thead>
<tr>
<th>Weeks</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>Researching current methods</td>
</tr>
<tr>
<td>3</td>
<td>Comparing found methods</td>
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<td>3-5</td>
<td>Implement best method to system</td>
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I am highly qualified to undertake this research, for I have a very broad background in many of the applied fields that this problem entails. I have taken many mathematic classes including linear algebra and multi-variable calculus, which allow me to understand complex equations. I understand how radar signal propagate with my multiple semester of Newtonian, Electricity and Magnetism, and Quantum Physics. I also have a large knowledge based in computer programming, which will allow me to implement and program software to accurately build a successful triangulation mesh.

5. CONCLUSION

There are many advantages to using radar over traditional photography or other analog types of imaging. Radar can work in the absence of light and can achieve greater resolution. Radar allows for easier 3D mapping of terrain, objects, and people. For these reason radar is still the preferred technique for use in spy-reconnaissance satellites, SAR plane stripmapping, and many other application [3]. Tons of research is being done to find new application for radar. [9-16]

Although the use of radar imaging provides a powerful tool for military and industrial applications one area in which it could be improved is accurately smoothing the surface of scanned 3-D objects. Future research in the area of mapping algorithms using envelopes and multi-resolution triangulation of scattered data could address issue not only in this radar imaging system, but all present systems [8].

4. ACKNOWLEDGEMENT

A brief acknowledgement section may be included here.

REFERENCES

Referenced Sources:


