Chapter 16
Clutter Removal Techniques in Ground Penetrating Radar for Landmine Detection:
A Survey

Deniz Kumlu
Istanbul Technical University, Turkey

Isin Erer
Istanbul Technical University, Turkey

ABSTRACT

Ground-penetrating radar (GPR) is a popular technique for landmine detection and widely used by military organizations for landmine clearance purposes. It is well known that GPR is greatly affected by clutter during the landmine detection process. The clutter can be reasoned by soil properties, depth of the buried landmine, different surface types, and ingredient of landmine materials. Thus, the detection of landmine becomes challenging, and clutter removal algorithm must be applied prior to any landmine detection scheme in GPR. In order to remove clutter, various algorithms are proposed, and they can be mainly separated into two groups such subspace-based methods and multiresolution-based methods. This chapter focuses on the performance analysis of these clutter removal algorithms on the simulated dataset that is created by using the gprMax simulation software where it contains four different challenging scenarios.

INTRODUCTION

Landmines are simple yet efficient devices, and they can be easily manufactured with a low cost. They are light, easily transported, simple to bury and difficult to detect. They are widely used by countries to protect their own borders but they can also be used by terrorist organizations to destroy/prevent access to borders, roads, bridges, water sources, and other strategically important regions or points. It is estimated that there are more than 110 million buried landmines in approximately 70 countries and every

DOI: 10.4018/978-1-5225-5513-1.ch016

year nearly 26000 victims die due to landmine explosions (Walsh & Walsh, 2003). Locating the buried landmines is extremely difficult even if they are in marked fields and unfortunately most of the minefields are unmarked. In addition, the landmine production technology is still improving, and most of the contemporary landmines are produced solely from the plastic material to reduce the detection probability and increase the false alarm rates. It is known that there are more than 600 types of landmines available and this makes the identification of landmines challenging even if they are detected. The United States currently spends approximately $100 million annually in mine clearance operations (demining) (Furuta & Ishikawa, 2009) and individual removal per mine costs $300-$1000. On the other hand, there is also development in landmine detection technologies (Robledo et al., 2009), and there are several landmine detection techniques available such as;

- **Probing the Ground:** Finding the location of landmines by probing the ground with a stick, and bayonet has been used for many years. For this process, trained soldiers probe the ground however, one small mistake can cost them their lives.
- **Trained Dogs:** Dogs can be trained to locate landmines by sniffing out the vapors from the ingredients of the explosives inside the landmines. However, this is also a slow and dangerous process. Since the vapor from the explosive penetrates the surrounding vegetation by 10 meters, it is impossible for the dogs to find the precise location of the landmines.
- **Metal Detectors:** Early landmines were composed of metal ingredients, and they can be easily detected by metal detectors. Therefore, mine manufacturers have improved the technology in landmine production by including low metal content or making them solely from plastic. Thus, the landmine detection capacity of metal detectors is reduced considerably.

These improvements in landmine production technology caused a decrease in the detection performance, and a new technology called ground-penetrating radar (GPR), is being developed to locate the landmines more accurately, and it emerges as a geophysical non-destructive tool to detect buried objects with low or no metal content (Daniels, 2009). GPR is currently one of the most popular and efficient subsurface sensing devices to investigate buried objects, especially plastic antipersonnel landmines and it has a wide range of other applications such as archeological research, concrete, bridge and road analysis, and geological profiling.

The components of GPR system consist of transmitting and receiving antennas, control and display units as shown in Figure 1. It works by sending pulses of ultra-high frequency radio waves from its transmitting antenna and records the strength, and the time of the reflected energy of the signal from the ground and various buried objects such as roots, stones, gravel and other materials with respect to their dielectric constant and electrical conductivity properties (Daniels, 2005). The received signal is used to create a detailed image of the underground, called a B-scan image or a GPR image. This image contains high amount of clutter caused by several reasons. The major ones are ground-bounce (caused by direct coupling between transmitting and receiving antennas), direct wave (reflection from the ground surface), and scattering from other non-mine objects such as roots, stones and non-uniform terrain conditions.

Generally, landmines are buried close to the surface and clutter dominates the reflected target signal since the ground-bounce is much higher than the target signal. Thus, the clutter degrades the performance of the landmine detectors, and causes an increase in false alarm rates in the non-target region. In addition, there are other factors which can affect the performance of GPR such as soil type, weather conditions,