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# Automated Ground Penetrating Radar hyperbola detection in complex environment

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Ground Penetrating Radar (GPR) systems are commonly used in many applications to detect, amongst others, buried targets (various types of pipes, landmines, tree roots ...), which, in a cross-section, present theoretically a particular hyperbolic-shaped signature resulting from the antenna radiation pattern. Considering the large quantity of information we can acquire during a field campaign, a manual detection of these hyperbolas is barely possible, therefore we have a real need to have at our disposal a quick and automated detection of these hyperbolas. However, this task may reveal itself laborious in real field data because these hyperbolas are often ill-shaped due to the heterogeneity of the medium and to instrumentation clutter.

We propose a new detection algorithm for well- and ill-shaped GPR reflection hyperbolas especially developed for complex field data. This algorithm is based on human recognition pattern to emulate human expertise to identify the hyperbolas apexes. The main principle relies in a fitting process of the GPR image edge dots detected with Canny filter to analytical hyperbolas, considering the object as a punctual disturbance with a physical constraint of the parameters. A long phase of observation of a large number of ill-shaped hyperbolas in various complex media led to the definition of smart criteria characterizing the hyperbolic shape and to the choice of accepted value ranges acceptable for an edge dot to correspond to the apex of a specific hyperbola. These values were defined to fit the ambiguity zone for the human brain and present the particularity of being functional in most heterogeneous media. Furthermore, the irregularity is particularly taken into account by defining a buffer zone around the theoretical hyperbola in which the edge dots need to be encountered to belong to this specific hyperbola.

First, the method was tested in laboratory conditions over tree roots and over PVC pipes with both time- and frequency-domain radars used on-ground. Second, we investigated the efficiency of this method for field data taken with a time-domain system connected to 400 and 900 MHz antennas in a forest environment. For all the tests explained above, the computational time is around 56 s for 10000 edge dots detected in a b-scan for the 900 MHz antenna and 228 s for the 400 MHz antenna. This value depends on the complexity of the images. For the given examples, the rate of non-detection is negligible and the rate of false alarms varies from 0 to 8.3% , although it is worth noting that these performance rates become difficult to evaluate for reflections that are ambiguous for our own eyes. Finally, we conducted a sensitivity analysis showing that all these criteria are needed and sufficient for a correct detection. In conclusion, the low computational time and its considerations to take into account the hyperbola irregularities make the proposed algorithm very suitable and robust for complex environments. The false alarms are easily removed by studying the continuity of the reflections between consecutive transects for linear targets such as pipes.

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