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Mathematical modeling and inverse problems in applications

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Mathematical modeling and inverse problems in applications



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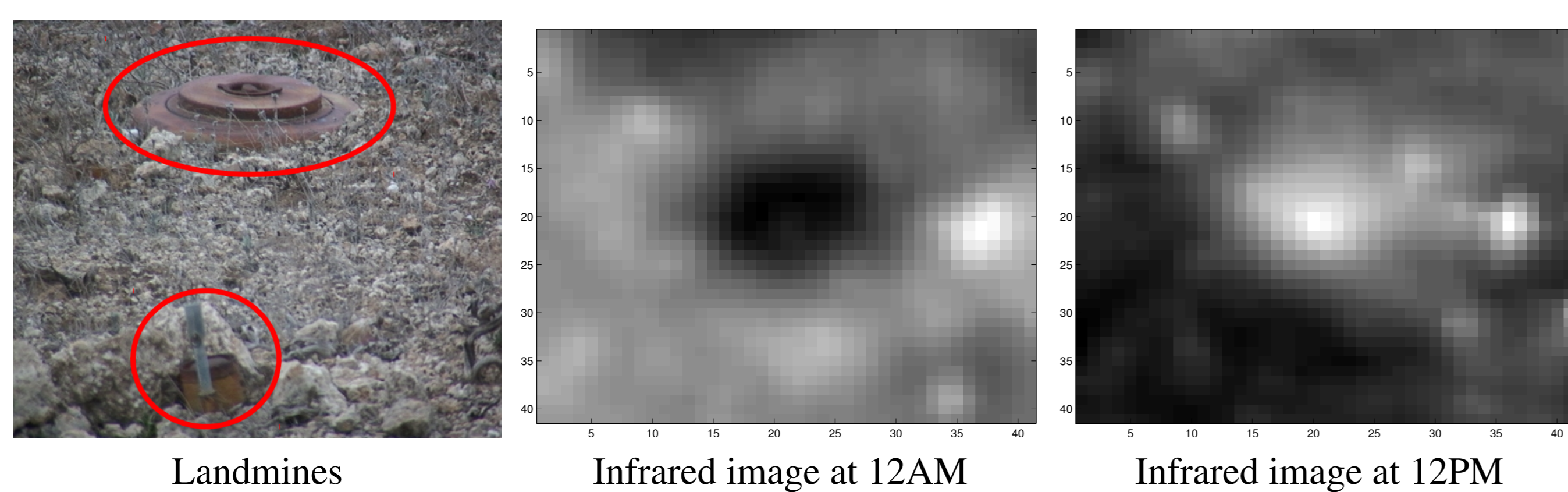
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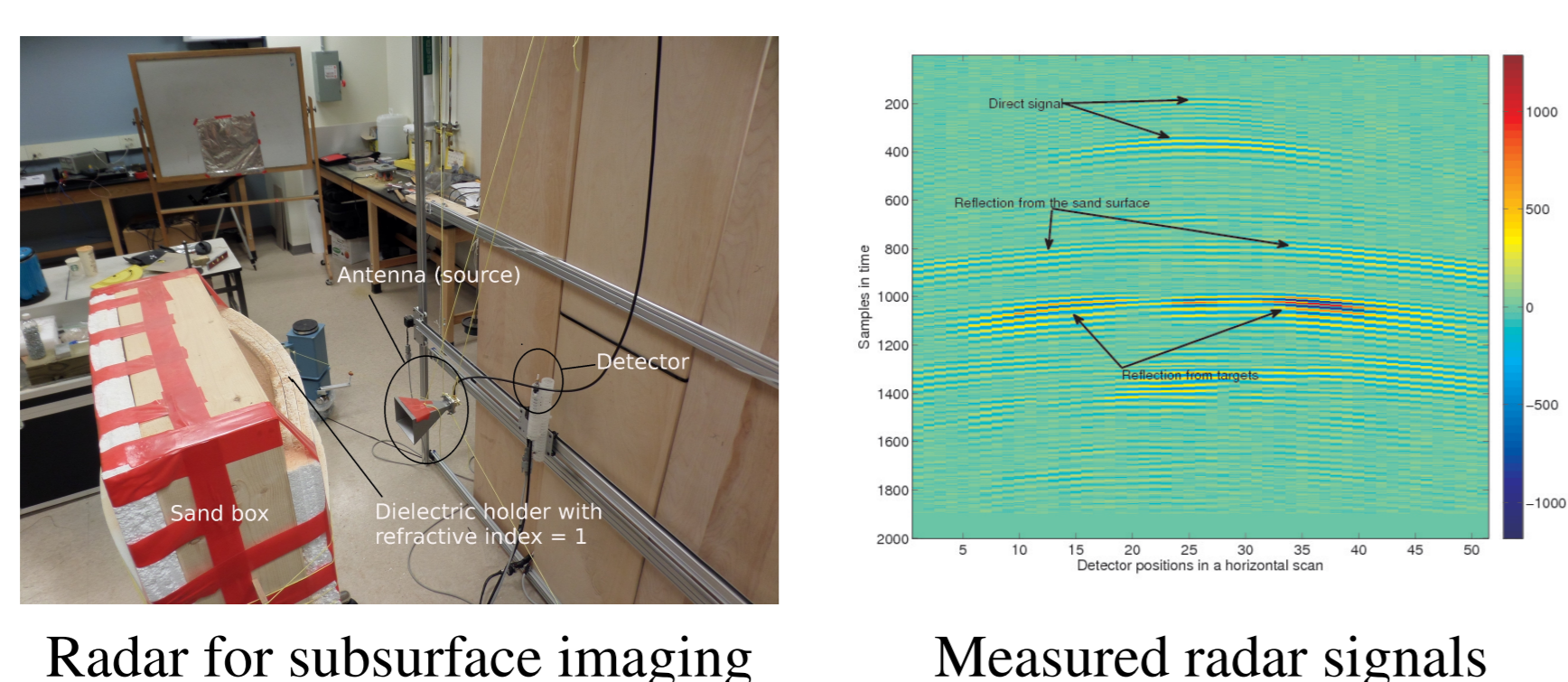
Examples of Applications of Mathematical Modeling

Mathematical models, based on ordinary or partial differential equations, are widely used to describe physical/chemical/biological processes and can be found in several applications: nondestructive testings, subsurface imaging, defense, medicine, environmental sciences, etc.

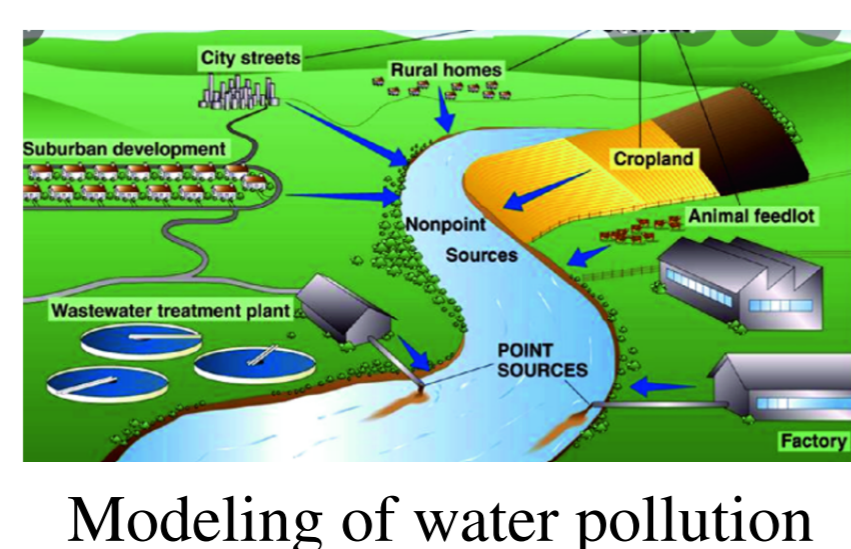
Modeling of soil temperature with landmines:



Modeling of waves in heterogeneous media:



Modeling of water pollution in rivers/streams/lakes:



Inverse Problems

Forward model: A mathematical model can be described by a problem of ordinary/partial differential equations of the form

$$F(u, u_t, u_x, u_y, \dots, \mathbf{p}) = 0,$$

where \mathbf{p} represents coefficients of the model (parameters of the medium).

Data: Measurements of the state variable u (physical/chemical/biological process) are conducted.

Inverse Problems:

- Model identification problem: Find a model (equivalently, the parameter set \mathbf{p}) which best fits the measured data.

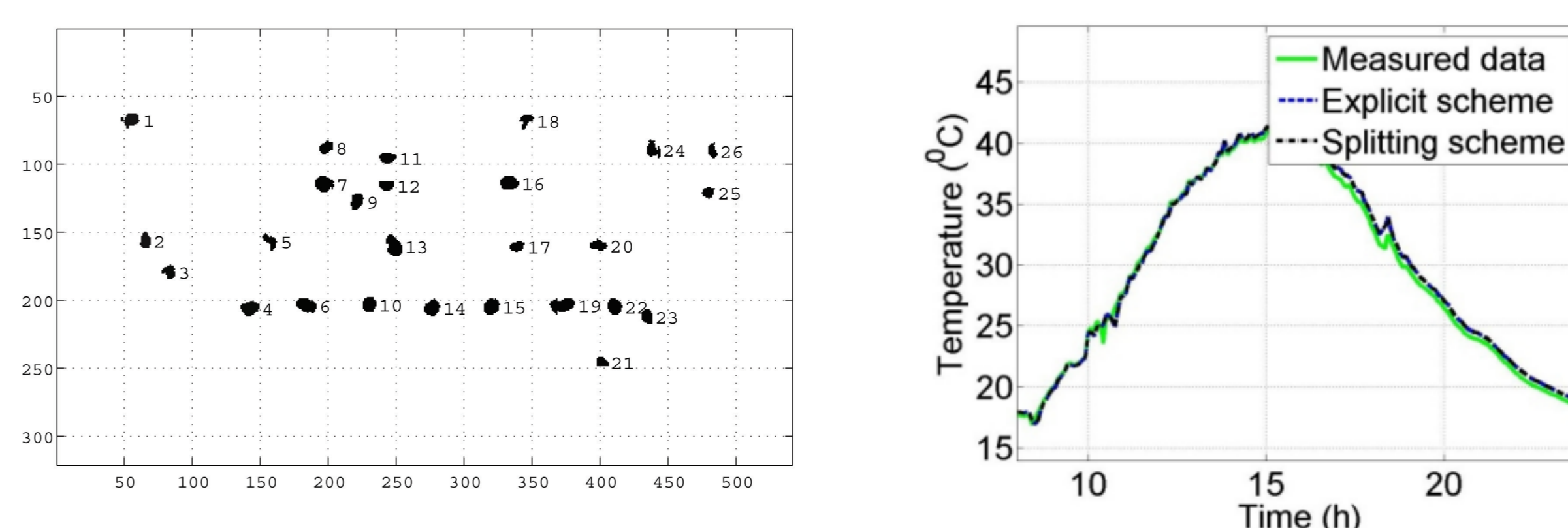
- Object detection/imaging: determine anomalies (objects) in a medium or reconstruct the physical properties of a medium (or an object).
- Source identification: Determine pollution sources.

Methods for Solving Inverse Problems

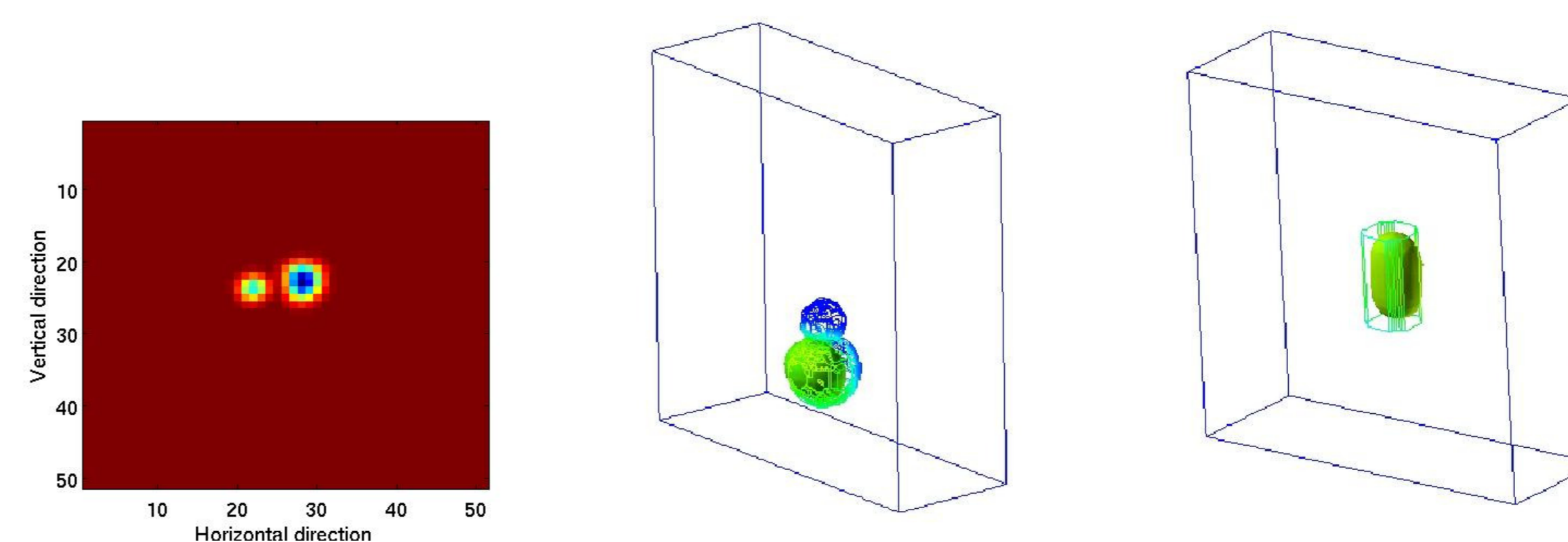
- Numerical methods for differential equations
- Data processing: image processing, signal processing
- Optimization methods for parameter estimation problems

Sample results of Inverse Problems

Detection of buried landmines using infrared cameras:



Detection of buried objects using ground penetrating radar:



Detection of water pollution sources:

