Optimizing Long-term Ground Water Monitoring Networks for Waste Disposal

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At many waste disposal facilities including nuclear waste disposal sites, the presence of toxic or radioactive wastes between the land surface and underlying aquifers poses a serious and ongoing threat to public health and safety. To reduce the risk associated with these industrial and radioactive by-products, a long-term ground water monitoring network (GWMN) design will be required.

The GWMN problem addressed here is the design of sensor network supporting ground water observations, such as may be associated with optimal observation and management of water supplies or subsurface pollutants in the ground water. The GWMN design problem is a good potential application domain because it represents a trade-off between the availability of data and their reliability. A common ground water monitoring problem is concerned with the location of contaminant sources, when transport model parameters are unknown or known with some uncertainty, and where monitoring points (which are costly) are to be located to minimize model prediction uncertainty for a given budget and collected data. Inverse modeling strategies have been used for estimating model transport parameters and reconstruct unknown source information.

The goal of monitoring network design is to identify the optimal sampling strategy from among many monitoring alternatives. The monitoring network design model seeks to identify the sampling strategy which minimize the trace of the model-prediction covariance;

$$\min \; trace\,Cov(\vec{p})$$

$$\text{subject to } \; \sum x_i c_i \leq B$$

where $\vec{p}$ is vector of model parameters, x_i is the indicator variable associated with measurement I; $x_i=1$ if i is taken and is zero otherwise, B is the budget, and c_i is the cost of sample i. The covariance matrix provides a quantitative measure of the reliability of model parameters and can be used to evaluate and compare alternative sampling strategies.

This kind of integer programming optimization problem is extremely computational task. A simple genetic algorithm (GA) known as combinatorial optimization technique is employed to solve the integer programming optimization problem. GA is known as an efficient tool for searching optimal solutions in optimization problems when the parameter hyperspace is large. Since GA includes a random search component, local minimum can be avoided and GA's operation does not require any knowledge of derivatives which are needed for numerical-analytical search methods for parameter estimation such as gradient-based ones. These makes the GA technique potentially strong for applications in highly non-linear cases.

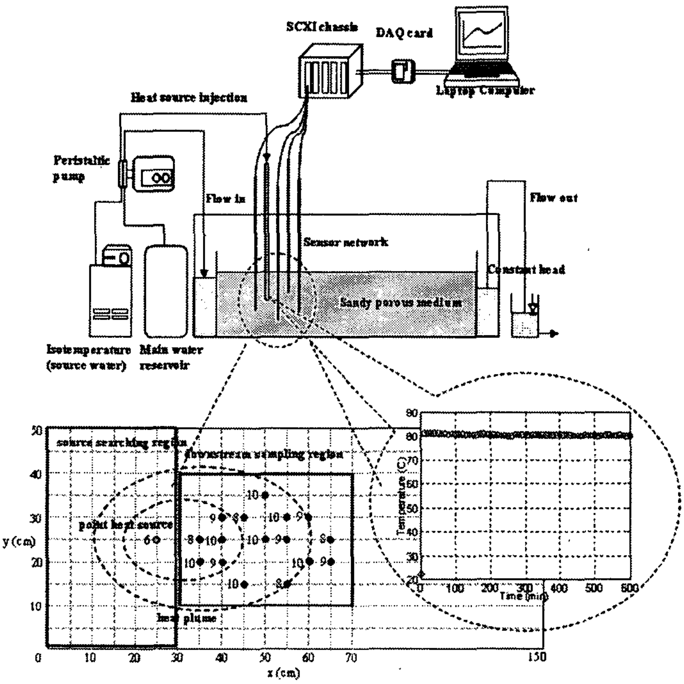
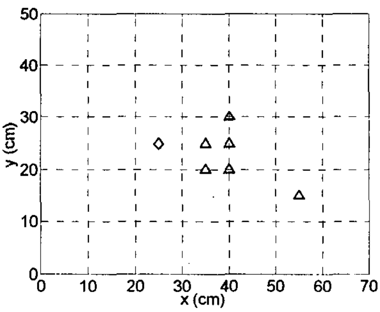
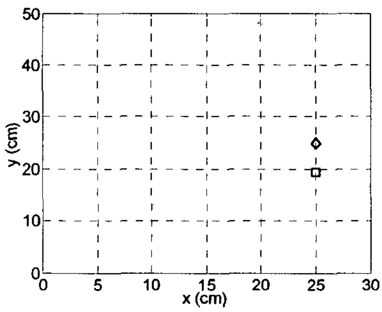


Figure 1. Plan view of the experimental layout for exercising the GWMN design algorithm



(a)



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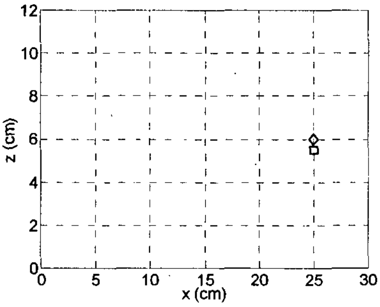

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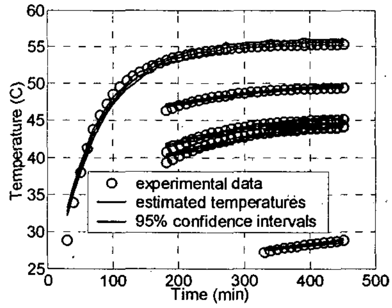

(d)

Figure 2. 6-sensor design: (a) monitoring network design with GA, (b and c) source identification with inverse modeling, and (d) comparison between experimental data and estimated temperatures