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# Data Assimilation Method for Environmental Problem

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## Abstract

Data assimilation is one of estimation method which combining a mathematical modeling and measurement data. Data assimilation need less measurement data and easy adapt to external influenced. Here, we present the application of Data assimilation to estimate the variable in environmental problem such as groundwater pollution concentration and air pollution concentration and debris flow distribution. One of data assimilation method is Kalman Filter. Some application of Kalman filter and its modification has been done to get more accurate estimation with less computation time. We used some modification of Kalman filter to solve environmental problem.

**Keywords:** Data Assimilation, Enviromental Problem, Estimation

## 1. Introduction

Environmental problem such as tidal prediction, flood control, groundwater pollution and others. The environmental problem influence healthy human and comfortability of lives. Therefore, it is necessary to estimate those variables which influence the environmental problems. The environmental problems usually are not deterministic problem, those are stochastic problems. We can estimate those variables with data assimilation method. In data assimilation, we combine the mathematical model of system with measurement data. Therefore, data assimilation method need less measurement data and it can adapt to various external input.

One of data assimilation method is Kalman Filter. Kalman filter is purposed by Kalman[1], it is applied to navigation satellite problem. Kalman filter has been applied in various fields, such as tracking problem, hydroynamics[2,3], weather prediction, and others. Kalman filter can be done for a linear dynamical stochastic system, but a lot of application problem is non linear system. Some researchers developed some modification of Kalman filter such as Reduced rank square root filter[4], reduced rank square root information filter[5,6], extended Kalman filter[1], ensemble Kalman filter[7], unscented Kalman filter[8,9] and others.

Here, we present the application of data assimilation in environmental problem, such as groundwater pollution distribution, air pollution distribution and debris flow problem. Here, we build mathematical model of system, discretize and do some simulation with Kalman filter or Kalman filter modification to estimate pollution distribution.

## 2. Data Assimilation

Data assimilation is a method to estimate the state variable or parameter of stochastic dynamical system. One of data assimilation method is Kalman filter. The algorithm of Kalman filter and also data assimilation method have to step there are prediction step or time update and correction step or measurement update. We predict the state variable at time $k + 1$ based on mathematical model of system, and based on some measurement data at

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time $k + 1$, we do some correction to prediction result. We continue to predict the state variable at time $k + 2$, based on estimation result at time $k + 1$ and mathematical model. We measure some data at time $k + 2$ to make some correction of prediction result, and so on. We do prediction and correction recursively. The algorithm of Kalman filter can be presented on Figure 1[1].

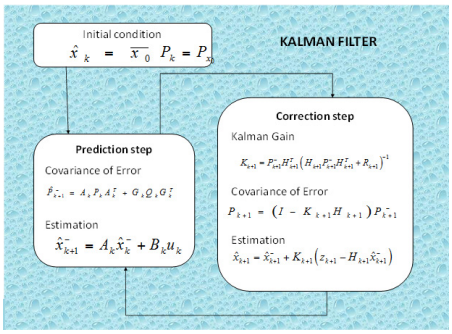


**Figure 1.** Kalman filter algorithm.

Due to the complexity of real system such as, non linear dynamical system or the system has a large scale, some researcher did some modification of Kalman filter to reduce error of estimation without increase the computational time.

# 3. Data Assimilation for Enviromental Problem

## 3.1 Groundwater Pollution Distribution

Groundwater is important for human life and enviroment. The quality of groundwater is influenced by pollution industry, the nature of surrounding and also pollution of river. We can't determine the concentration of pollution for all area in the city of village. Therefore, we need to estimate the concentration of groundwater pollution. By using those information. The scheme of groundwater pollution research is presented on Figure 2[10].

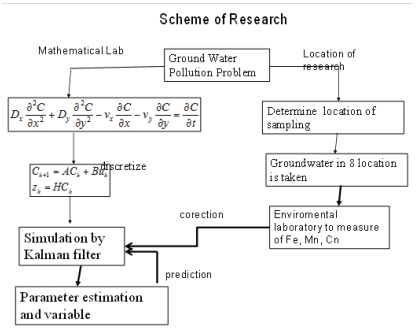


**Figure 2.** The Scheme of Research.

In this simulation, we can estimate the concentration of groundwater pollution based on some measurement data, such as Figure 3.

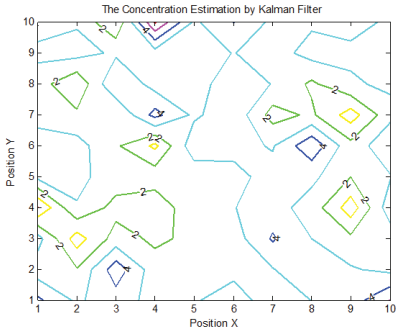


**Figure 3.** Contour of Mn Concentration.

## 3.2 Air Pollution Distribution

Such as groundwater quality, the air quality also influence human healthy and confortability of life.

The mathematical model of air pollution transport is

$$\frac{\partial C}{\partial t} = -\left[\frac{\partial}{\partial x}\left(U_x C - D_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(U_y C - D_y \frac{\partial C}{\partial y}\right)\right]$$

In case, we estimate the air pollution concentration in Surabaya. Suppose, we descretize the location of city in 100 grids such as Figure 4. And we can measure the concentration of air pollution in 5 locations. The scheme of air pollution research is presented on Figure 5[11].

**Figure 4.** Grid of location.

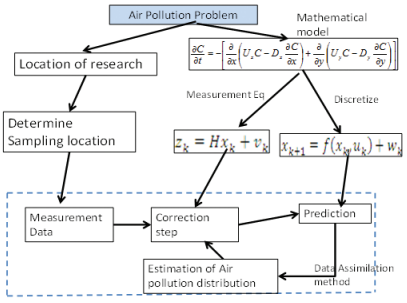


**Figure 5.** The Scheme of Air Pollution Estimation.

Based on mathematical model we predict the concentration of air pollution and based on measurement data in 5 locations, we make the estimation air pollution concentration in 100 locations.

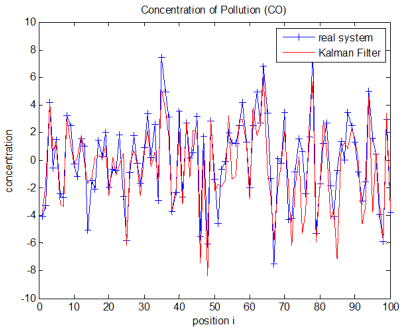


**Figure 6.** The estimation of pollution concentration.

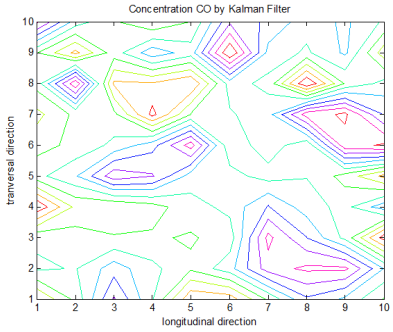


**Figure 7.** The contour of CO concentration in air.

Figure 6 states the concentration estimation of CO by using Kalman filter almost same as the real concentration of CO in the air.

### 3.3 Debris Flow

When the volcano exploded some material of mountain is thrown to surrounding of mountains. Some material will cover the river and make sedimentation in the river. The hard rain will make the sedimentation move in large volume, fast and uncontrollable. Those moving sedimentation we call debris. Debris flow contains water, rock, sand and mud. Debris will destroy the human, animals, plants, houses and anything which it pass. To reduce the damage of debris flow, it is necessary to estimate the distribution of debris flow. The mathematical model of debris flow is[13]

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}(u_m M)+\frac{\partial}{\partial y}(v_m M)=-g\boldsymbol{h}\,\frac{\partial H}{\partial x}-\frac{\tau_{bx}}{\rho}$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}(u_m N)+\frac{\partial}{\partial y}(v_m N)=-g\boldsymbol{h}\,\frac{\partial H}{\partial y}-\frac{\tau_{by}}{\rho}$$

$$\frac{\partial \boldsymbol{h}}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0$$

By using the data assimilation method, we can estimate the value of *M, N* and *h* are flux in lateral, longitudinal position and the height of debris flow along the river. At the moment, we still doing research the application of data assimilation to estimate debris flow. By using data assimilation we will can estimate the flow of debris such that we can avoid or reduce the damage of debris.

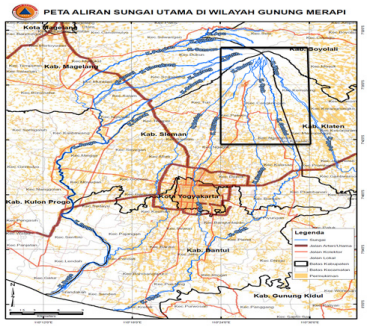


**Figure 8.** The area of debris flow estimation.

In this research, we take Kali Gendol and Kali Putih, in Merapi mountain, Center of Java as case study.

## 4. Conclusion

From those discussion and the simulation we conclude that

- Data assimilation can be used to estimate the groundwater pollution concentration, air pollution concentration.
- By using data assimilation, we need less measurement data to estimate for all region.
- Data assimilation will apply to estimate the debris flow.

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