FIG Working Week 2007

Fitness Analysis of Height Variation for GPS Monitoring Site

C-C Chang*, P-S Hung** and H-Z Chen***

* Department of Information Management, Yu-Da University, Taiwan
** Department of Land Management, Feng-Chia University, Taiwan
***Land Survey Bureau, Taiwan

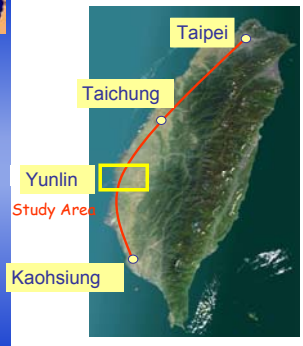
Hong Kong 13-17 May 2007

Motivations

- A long-term subsidence occurred in the middle-south of Taiwan
- Accompanied with heavy withdrawal of under-ground water in the coastal regions
- Subsidence area is enlarged towards inland and potentially damages the engineering structure of the Taiwan High Speed Rail (THSR)

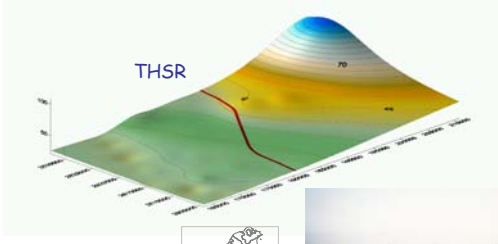
Background

Taiwan High Speed Rail (THSR)



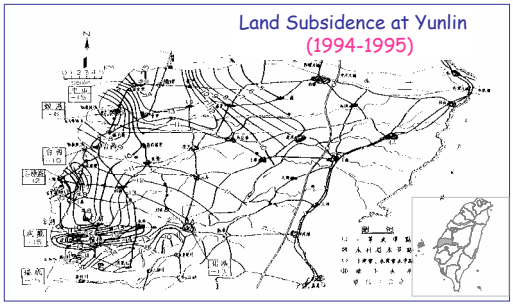
Track Bridge

Significant Subsidence Area

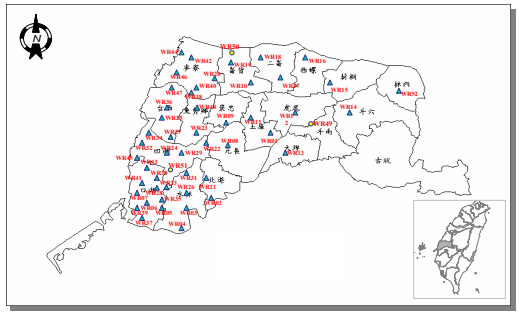


Yunlin County

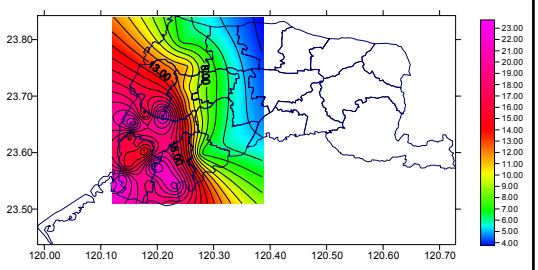
Monitoring by Spirit Leveling



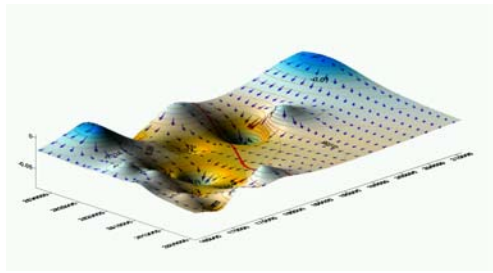
GPS Set-up for Monitoring



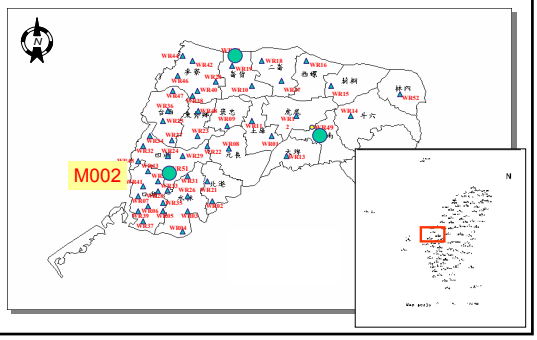
Subsidence Rate (1998)



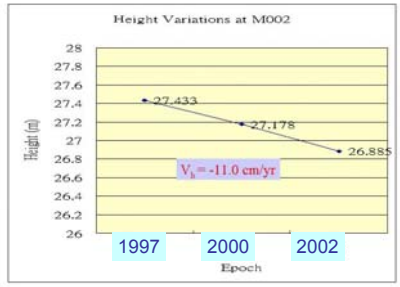
Subsidence (Jan-Nov 2000)



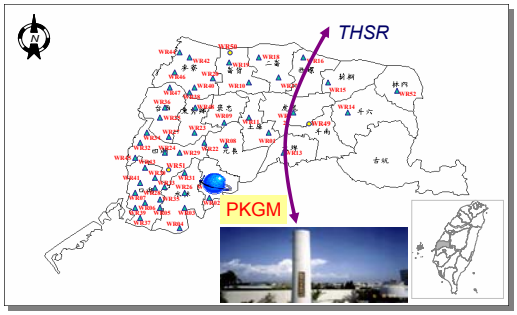
Control Stations of TWD97



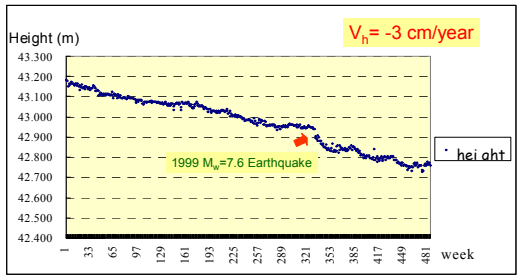
Height Variations at M002



GPS Tracking Station

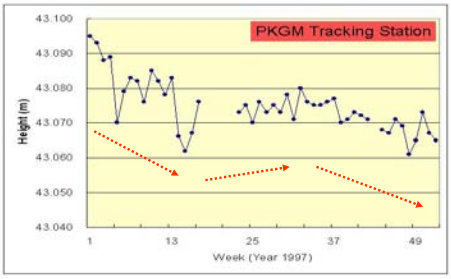


Weekly GPS Solutions at PKGM (1995-2004)



Weekly GPS Heighting in 1997

Correlated to Seasonal Descending ?



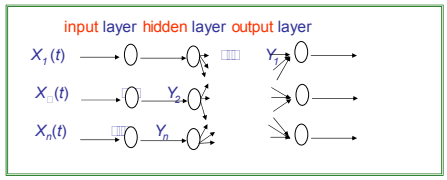
Seasonal Subsidence Rates

Year	Annual Rate (cm/year)	
	Summer	Winter
1995	- 6.6	-13.8
1996	- 1.4	- 8.8
1997	1.3	- 4.4
1998	1.4	- 9.5
1999	- 3.6	-12.2
2000	2.4	- 4.4
2001	- 4.1	- 9.8
Average	- 1.5	- 9.0
All-Span (1995-2001)	- 3.1	

Objectives of this Study

- Establishing a forecast technique by using a relatively short term of GPS monitoring data
- Estimating the up-coming level of subsidence to further prevent any possible damage
- Testing the fitness of the estimation models with a continuous GPS data set

Artificial Neural Network



- Imitating the pattern of human thought and inducing an operation rule through learning process to build up its recognition and fore-cast capability

ANN Transfer Function

$$Y_j = f(\sum_{i=1}^{n} W_{ij} X_i - \theta_j)$$

W_{ij} is the weight connecting layer node *i* and *j*
θ_j is the threshold of node *j*

- It transfers a set of input/output samples into a non-linear optimisation process by finding rules from massive data
- Three-layer BP network's training process is composed of a forward and back propagation

Grey Forecast Theory

- A common GM(1,1) model is approximate to a differential model

$$\frac{dx}{dt} + ax = b,$$

$$\hat{x}^{(1)}(k+1) = \left[x^{(0)}(1) - \frac{b}{a}\right]e^{-ak} + \frac{b}{a}$$

$$\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k)$$

$$x^{(1)}(k) = \sum_{m=1}^{k} x^{(0)}(m)$$

$$z^{(1)}(k) = 0.5x^{(1)}(k) + 0.5x^{(1)}(k-1)$$

$$C = \sum_{m=1}^{k} z^{(1)}(m), D = \sum_{m=1}^{k} x^{(0)}(m), E = \sum_{m=1}^{k} x^{(0)}(m) * x^{(1)}(m), F = \sum_{m=1}^{k} [z^{(1)}(m)]^2$$

$$a = \frac{C*D - 4*E}{4*F - C^2}, b = \frac{D*F - C*E}{4*F - C^2}$$

- Modelling with very less data to estimate the variables for system's future behavior

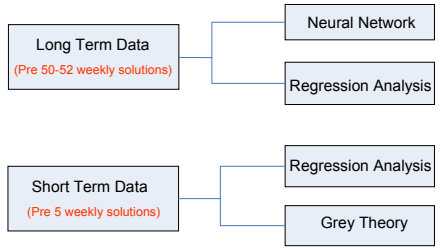
Regression Analysis

$$h_i = at_i + b$$

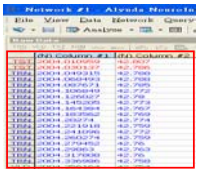
a, b coefficients represent the slope and intercept
t_i is defined as time variable
h_i is the height measurement

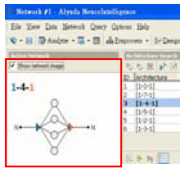
Variable h_i can be predicted using independent variables of t_i

Data Sets & Test Models



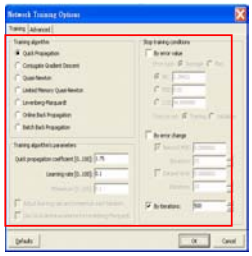
ANN Samples & Hidden Layers

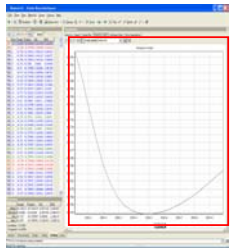

ANN Sample Data


ANN Hidden Layers

- Using Alyuda Neuro Intelligence Version 2.1 software
- Training, testing and verifying samples are randomly made
- Optimum hidden layers are automatically determined

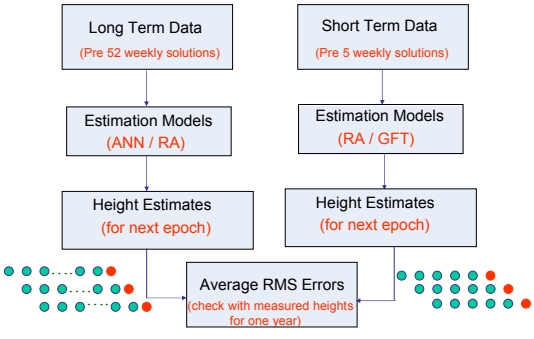
ANN Training Algorithm & Testing Network





Default option of quick propagation algorithm is applied with the coefficient of 1.75 and learning rate of 0.1

Height Estimations & Errors

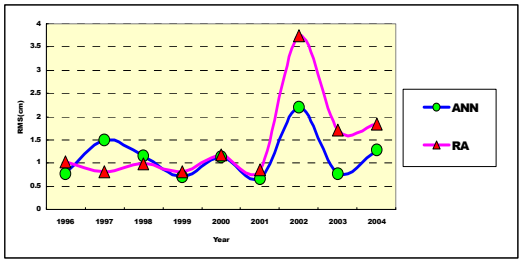


Fitness Analysis

Height estimation error based on long-term data

Year of Data	ANN model (cm)	RA model (cm)
1996	0.8	1.0
1997	1.5	0.8
1998	1.2	1.0
1999	0.7	0.8
2000	1.1	1.2
2001	0.7	0.8
2002	2.2	3.7
2003	0.8	1.7
2004	1.3	1.8
Average	1.1	1.4
Standard Deviation	0.5	0.9

Fitness Errors based on Long Term Data



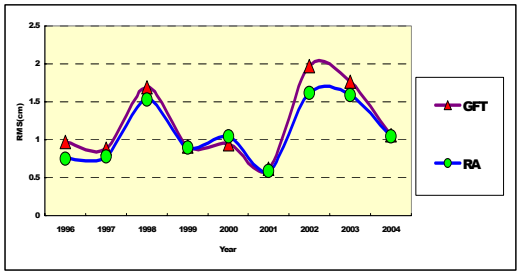
ANN model provided a **better** performance of 27% than that of using RA model

Fitness Analysis

Height estimation error based on short-term data

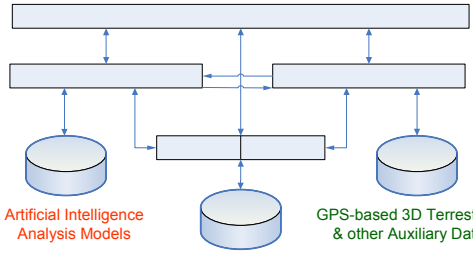
Year of Data	GFT model (cm)	RA model (cm)
1996	1.0	0.7
1997	0.9	0.8
1998	1.7	1.5
1999	0.9	0.9
2000	0.9	1.0
2001	0.6	0.6
2002	2.0	1.6
2003	1.8	1.6
2004	1.1	1.1
Average	1.2	1.1
Standard Deviation	0.5	0.4

Fitness Errors based on Short Term Data

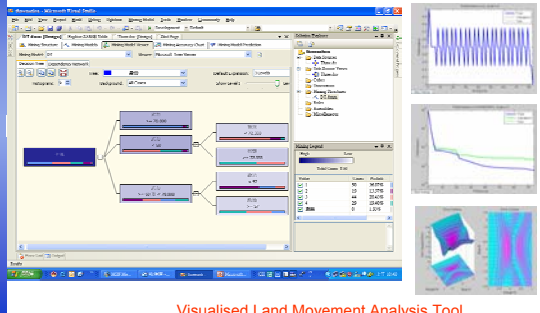


Fitness based on RA or GFT model with short-term data is **equivalent** to the ANN model using long-term data measured at the significant land subsidence area

Future Study



Information System



Visualised Land Movement Analysis Tool