A GEO Satellites Tracking System of the Moving Ground Station

Hsieh-Ju Wang, Te-Jen Su and Sher-man Ong

Abstract—**In this paper, the intelligent-based algorithm called Particle Swarm Optimization (PSO) which can be implemented by any programming languages with few parameters to adjust is employed to design a GEO (Geostationary Earth Orbit) satellites tracking system of the moving ground station. The system can be applied to a multimedia communication satellite anywhere and used only for Line-of-Sight communication with satellites. Using the information from a global positioning system, gyroscope and integrated receiver decoder (GEO satellite signal strength) to calculate the errors of change by the step-tracking method and particle swarm optimization algorithm, then the elevation angle and the azimuth angle of the target will be tracked efficiently.**

Index Terms—**Particle Swarm Optimization, Satellite Communication, Step-Tracking Method**

I. Introduction

In general, the method used for tracking to GEO satellites is usually the step-tracking method. It is based on signal level measurements between small angular step displacements of the parabolic antenna and is widely used in low grade earth station systems of near geostationary satellites [1].

Particle Swarm Optimization (PSO) is a population based stochastic optimization technique developed by James Kennedy and Russell Eberhart in 1995 [2,3], inspired by social behaviour of bird flocking or fish schooling. PSO is based on swarm intelligence, and it's somewhat different from other evolutionary algorithms as each particle in the swarm has a velocity, a *pbest* position and a *gbest* position to record and exploit its historical best position [12]. PSO could be easily implemented in most programming languages and has proven both very effective and quick for a diverse set of optimization problems. The overall objective of this paper is to search and track the GEO satellites by using this modern heuristic optimization algorithm. More specifically, the Particle Swarm Optimization technique will be applied to the problems described in this paper.

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II. System Configuration

A. Structure of the Tracking System

The structure of the tracking system of a moving ground station for GEO satellites as shown in Fig. 1 [4]. The moving ground station utilizes the GPS receiver to determine where the station position is [5,7,8], and calculate the relative position of the GEO satellites by a computer program, then the motor controller adjusts the azimuth (*Az*) and elevation (*El*) of the antenna. The signal which is received from the satellite and passed through the parabolic antenna would be transformed into an amplitude gain control (AGC) signal by an integrated receiver decoder (IRD) then sent into the main program of the mobile computer, to compare the GPS information with the moving directon and the acceleration which are read from the gyroscope, to change the azimuth and elevation angles to be sure that the status of the signal received is normal [11,13,14].

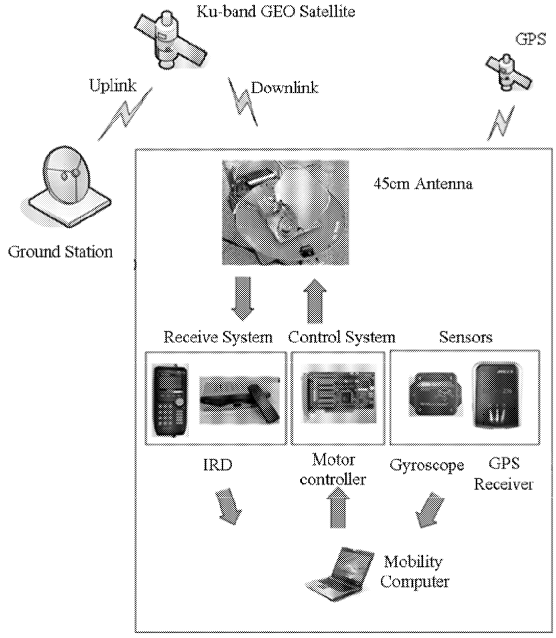

Figure 1: The tracking system of a moving ground station for a GEO satellite.

A gyroscope is a device for measuring or maintaining orientation, based on the principles of conservation of angular momentum. The essence of the device is like a spinning wheel on an axle [6]. The device, once spinning, tends to resist changes to its orientation due to the angular momentum of the wheel. In physics this phenomenon is also known as gyroscopic inertia.

There are two ways to adjust the orientation of the antenna, it's the azimuth angle (*Az*) and the elevator angle (*El*) [4,6], as shown in Fig. 2. For the moving ground station, the angular motion can be categorized by *yaw*, *pitch* and *roll* [6,11], as shown in Fig. 3. Yaw is rotation about the vertical axis, pitch is rotation around the lateral or transverse axis and roll is rotation around the longitudinal axis. With the use of gyroscopic inertia sensing instruments, we can easily obtain the *yaw*, *pitch* and *roll* angles.

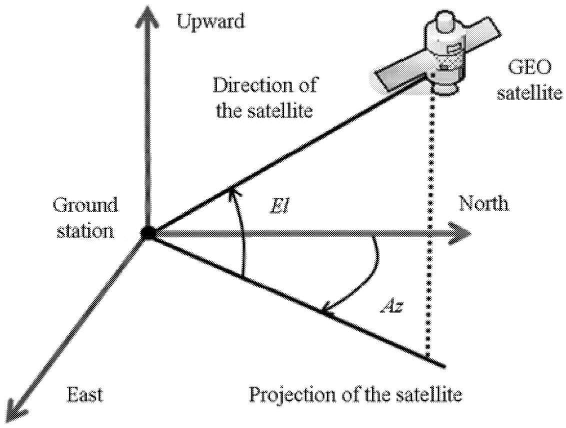

Figure 2: Diagram of azimuth and elevation

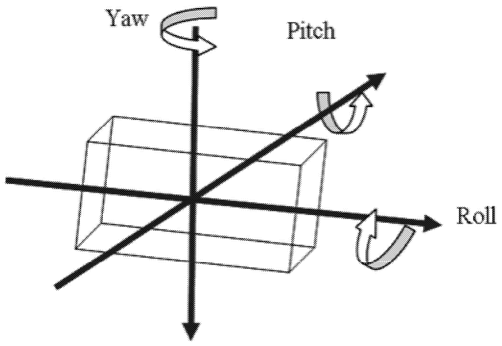

Figure 3: *Yaw*, *Pitch* and *Roll* axis of a moving object

B. Particle Swarm Optimization (PSO)

In PSO, suppose that the search space is D-dimensional, and then the *i*-th particle is represented as $X_i = (x_{i1}, x_{i2}, \ldots, x_{iD})$. The velocity (rate of the position change) of this particle is denoted as $V_i = (v_{i1}, v_{i2}, \ldots, v_{iD})$. The best previous position of the *i*-th particle is represented as $P_i = (p_{i1}, p_{i2}, \ldots, p_{iD})$. In other words, P_i involves the best previous position which Xi has visited (the local best position called *pbest*). The index of the best particle among all the particles in the swarm is defined as the symbol (the global best position is called *gbest*). The particles are manipulated according to the following equations: In its canonical form, Particle Swarm Optimization is modeled as follows [12]:

$$v_{id}(t+1) = w * v_{id}(t) + c_1 * rand()_1 * (p_{id} - x_{id}) + c_2 * rand()_2 * (p_{gd} - x_{id}) \tag{1}$$

$$x_{id}(t+1) = x_{id}(t) + v_{id}(t+1) \tag{2}$$

where

$v_{id}(t+1)$: velocity of particle *i* at iteration *t*+1
$v_{id}(t)$: velocity of particle *i* at iteration *t*
$x_{id}(t+1)$: position of particle *i* at iteration *t*+1.
$x_{id}(t)$: position of particle *i* at iteration *t*
c_1 : acceleration coefficient related to *pbest*
c_2 : acceleration coefficient related to *gbest*
$rand()_1$: random number uniform distribution *U*(0,1)
$rand()_2$: random number uniform distribution *U*(0,1)
p_{id} : *pbest* position of particle *i*
p_{gd} : *gbest* position of particle *i*
w : inertia weight

The advantages of PSO are that PSO is easy to implement and there are few parameters that need to be adjusted. PSO has been successfully applied in many areas: function optimization, artificial neural network training, fuzzy system control, and other areas where other optimization algorithms can be applied.

III. Tracking System for GEO Satellites

First, we have to search for a satellite that we wish to track before we start tracking the satellite. Fig. 4 is the flowchart of the satellite searching by using PSO. When we search satellites for the first time, PSO would generate n particles with random velocity and position, after determining the fitness values of *i*-th particle, f_i, the *pbest* and *gbest* values are updated by comparison of f_i, $f_{i,p}$ and f_g for *i* times every iteration in the right part of Fig. 5, and the searching program would be restarted if the PSO runs over the maximum of iterations.

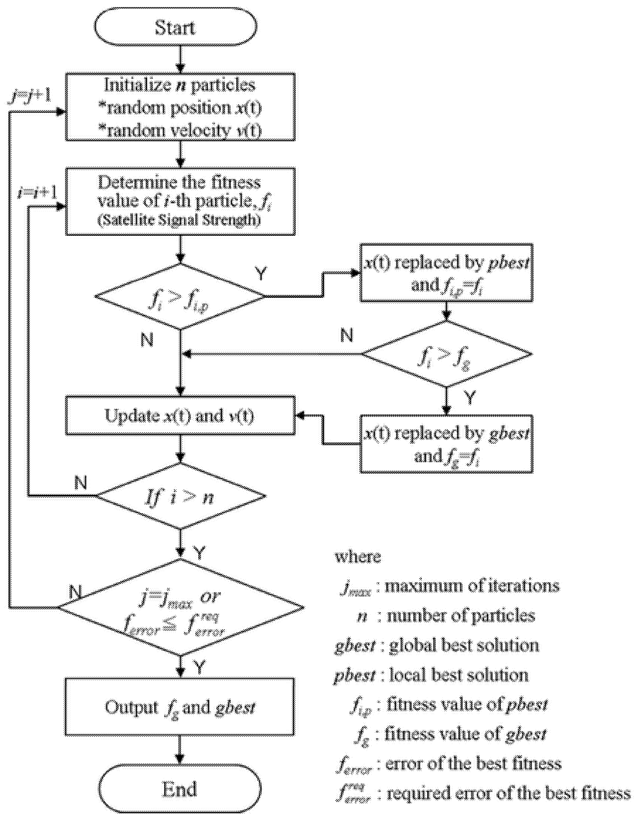

Figure 4: Flowchart of satellite searching by PSO.

When PSO finds a satellite signal which has a signal strength that is good enough, it will be interrupted and changed to step-tracking mode automatically. But if the signal is lost for a fixed time, the program will go back to PSO searching mode and searching for satellites again.

The step-tracking method is based on the hill-climbing method as shown in Fig. 5, the method searches to maximize the signal level through iteration, where constant size angular steps are taken in orthogonal coordinate directions in turn, and the next step will be decided by comparing the signal levels before and after a step [1, 9, 10], and Fig. 6 is the flowchart of the step-tracking.

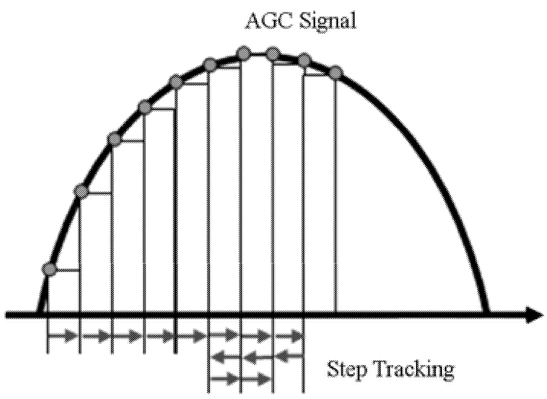

Figure 5: Step-Tracking diagram.

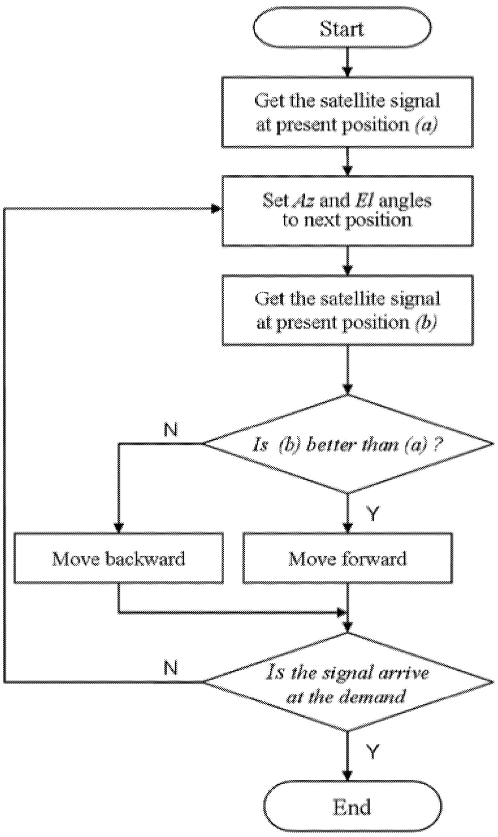

Figure 6: Flowchart of Step-Tracking.

IV. Simulation and Results

By using our proposed method, the parameters of our PSO searching algorithm as in Table 1, It will be reset for searching until it finds a satellite. Fig. 7 shows that by using PSO searching, the signal strength to rise to 8.5V. It only needs 39 iterations, this for the signal to be searched and locked at the 39th iteration.

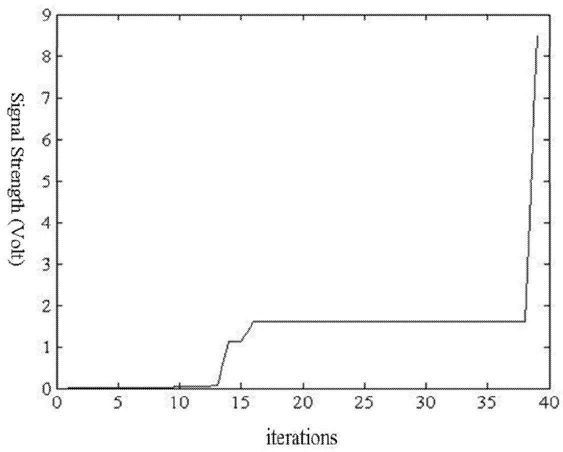

Figure 7: Iterations of PSO searching.

After the simulation, we now use real equipment to implement the system and test the condition of the receiving signal. First, we take the latitude, longitude and altitude information from the GPS receiver and calculate the moving direction and the acceleration from the gyroscope, it can get a relative position of the satellite which we wish to track and the estimation of azimuth and elevation angles should be set to the antenna.

The static searching result as shown in Fig. 8, searches for a satellite by PSO from 0 to 18s for 32 iterations until the signal strength is good enough at 18s. Fig. 9 shows the real dynamic situation of this GEO satellite tracking system, when the first time PSO finds a satellite at 21 to 27s, then the program switched to step-tracking until about 41s, we had the moving station turn right 90 degrees suddenly and the signal was lost, it took about 3 to 5s to adjust the *Az* and *El* angles, the satellite signal was recovered to a normal state and continued tracking the satellite.

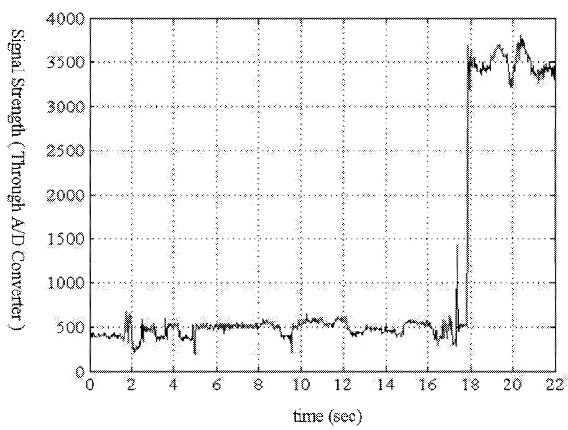

Figure 8: PSO found a satellite successfully.

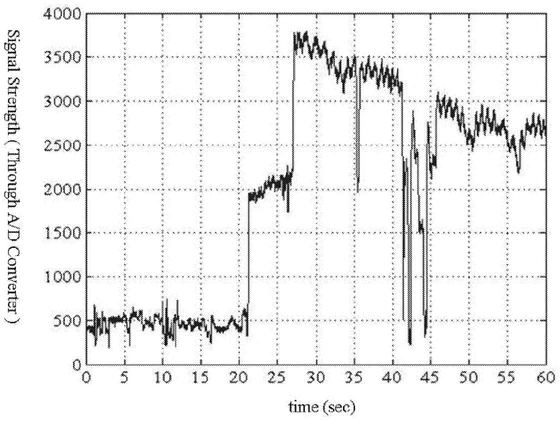

Figure 9: The signal strength varied when moving

V. CONCLUSION

Particle Swarm Optimization (PSO), which is applied to a GEO satellites tracking system for a moving ground station, is proposed. It saves more time of the first time we search satellites than without using PSO, this method not only increases the satellite searching speed, but also increases the successful rate of our first search for a satellite. By the uncertainty of the position of the moving ground station, our proposed method still can search out and track the GEO satellite and it only needs about 20 to 40s. In a real situation, even if there are 2 degrees of angle difference when the antenna received the signal from GEO satellites, the moving ground station could still track the satellite successfully and normally, thus these angle differences could be accepted.

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Table 1: PSO parameters setting.

The number of swarm size n	5
The maximum position x_{max}	360
The maximum velocity v_{max}	20
Acceleration coefficient c_1	2.8
Acceleration coefficient c_2	1.3
Inertia weight w	0.8
Maximum iterations j_{max}	1000