Application of Genetic Algorithm with Optimization of GNSS Satellite Combination in Kinematic Positioning Mode: Case Study using GPS, GLONASS and Beidou Data

Wongsuwan, A. and Satirapod, C.*
Department of Survey Engineering, Chulalongkorn University, Bangkok, Thailand
E-mail: assawinee.wong@gmail.com, chalermchon.s@chula.ac.th
**Corresponding author*

Abstract
Kinematic GNSS positioning mode has been widely used in many applications. There are various techniques to obtain high-precision kinematic positioning results. One such technique is relative positioning based on differential carrier phase-based positioning. This technique may produce high accuracy positioning solutions in good, obstruction free signal environments. However, in less favorable observing environments (i.e., urban areas with tall buildings or tree canopy), the remaining errors can cause bad or unreliable positioning results. The quality of the solution mainly depends on the ability to resolve the ambiguities to their correct integer values. The process is known as Ambiguity Resolution (AR). AR success relies on the removal of unreliable observations data before data processing among others. Generally, the removal is carried out manually and may be considered as a trial-and-error procedure. The user has to process over and over until he gets a satisfactory result. Obviously, the manual removal is time consuming. In addition, it requires skills of an experienced user. To avoid such challenges, an automatic procedure is recommended. This paper introduces an optimization procedure based on the genetic algorithm (GA). GA is a global optimum search algorithm based on natural evolution that has been extensively used in various fields of study. GA allows optimally selecting the best GNSS satellite combination and improving the percentage of the ambiguity-fixed solutions in kinematic positioning mode. The numerical results demonstrate the improvements in ambiguity resolution rate when GA is applied comparing to the conventional method. Overall, the proposed GA-based method can improve the ambiguity resolution rate at 48.85%, 50.08% and 36.79% for 3.8 km, 6.7 km and 23.2 km baseline lengths respectively.

1. Introduction

Genetic Algorithm (GA) has been extensively used in various fields of study and applications (Holland, 1975). They have been used to solve a wide variety of combinatorial optimization problems. The Genetic Algorithm (GA) is based on an iterative procedure, an "evolutionary" process, in which it tries to extract the best solution out of a search space without any prior knowledge or mathematical model related to the problem. The operators of Genetic Algorithm (GA) are representation, initialization, selection, crossover scheme (type and probability), mutation scheme (type and probability), and replacement percentage operators. This can be done with the aid of an optimization technique known as the genetic algorithm (GA). The optimization techniques have been used to solve in surveys.

Global Navigation Satellite Systems (GNSS) provide 24-h coverage for the user with highly accurate three dimensional positions and timing information in all-weather at most locations worldwide. In addition, these systems play an important role in many real-life applications (e.g. in early warning and management of the effects of disasters, monitoring of the environment, agriculture, transport and timing, etc.). Surveying is another area where space technology is having a big impact in determining locations and changes in locations within short observational periods and over long distances. The most widely known satellite navigation systems: are the American Global Positioning System (GPS), the Russian GLObal Navigation Satellite System (GLONASS), and the forthcoming BeiDou or Compass of China Satellite. This paper is to present a method with aiding of Genetic Algorithm (GA) to optimize the selection of the best GNSS satellite (GPS, GLONASS and BEIDOU) combination in kinematic positioning mode. The obtained results reveal that the aiding of

ISSN 1686-6576 / © Geoinformatics International

Genetic Algorithm (GA) can provide the best GNSS satellite (GPS, GLONASS and BEIDOU) combination and improve the success rate of ambiguity resolution. It is employed to search for the best satellite combination which yields the highest number of ambiguity-fixed solutions in kinematic positioning. The proposed method is demonstrated in a Post-Processed Kinematic (PPK) mode using sample data from receivers in Thailand.

2. Genetic Algorithm (GA)

Genetic Algorithm (GA) is the global optimum search algorithm that mimics the natural evolution known as Darwinian Evolution. Because of its advantages (simple, supports parallel computation, immune to noise), it has been extensively used in various fields of study and applications (Holland, 1975 and Sivanandam and Deepa, 2008). The idea of Genetic Algorithm (GA) is based on the evolutionary process of biological organisms in nature. During the course of the evolution, natural populations evolve according to the principles of natural selection and "survival of the fittest". Individuals which are more successful in adapting to their environment will have a better chance of surviving and reproducing, whilst individuals which are less fit will be eliminated. This means that the genes from the highly fit individuals will spread to an increasing number of individuals in each successive generation. The operators of Genetic Algorithm (GA) are representation, initialization, selection, crossover scheme (type and probability), mutation scheme (type and probability), and replacement percentage operators (Figure 1). The basic steps of the developed GA are therefore:

Step 1: Generate a family of initial chromosomes (solutions),

Step 2: Calculate the fitness of each chromosome,

Step 3: Select two 'parent' chromosomes from the family using binary tournament selection,

Step 4: Produce a child chromosome as an offspring from the parents using a crossover operation,

Step 5: Allow the child to mutate,

Step 6: Calculate the fitness of the child,

Step 7: Replace the least fit member of the family with the child providing that the child is fitter and is not already a member of the family,

Step 8: Stop if the number of predefined cycles has been reached, otherwise go to step 3.

2.1 The Population Type

As mentioned in the previous section, there are several types of population that GA can understand such as binary, real number and so on. To obtain reliable and accurate positioning, the best satellite combination will be searched for by the GA. Thus, all satellites must be encoded into a proper format. In this study, satellites are encoded using the binary format. Therefore, each satellite will be represented by either '0' (off) or '1' (on). The satellite vehicle number (SVN) will be represented by a location of bit in the bits string. . Examples of encoding are shown in Figure 2.

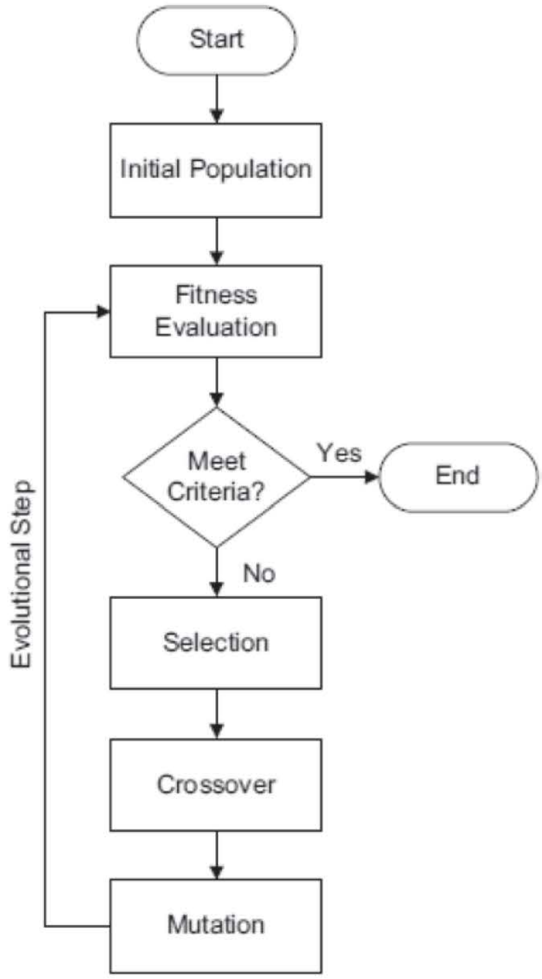

Figure 1: Operating procedure of standard Genetic Algorithm (Srinuandee and Satirapod, 2015)

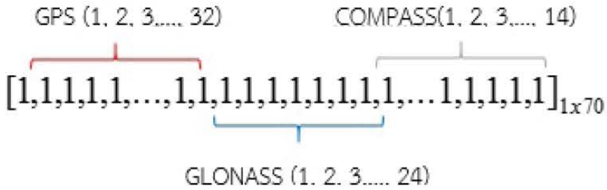

Figure 2: The Encoding of problem in bits string

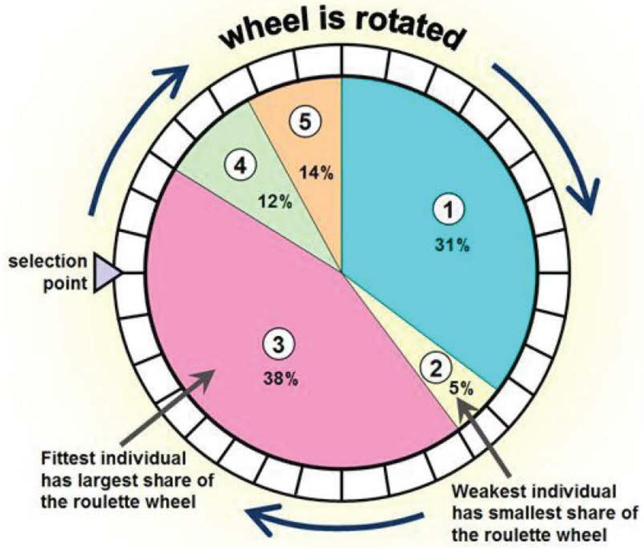

Figure 3: Roulette Wheel Selection (http://www.edc.ncl.ac.uk/highlight/rhjanuary2007g02.php)

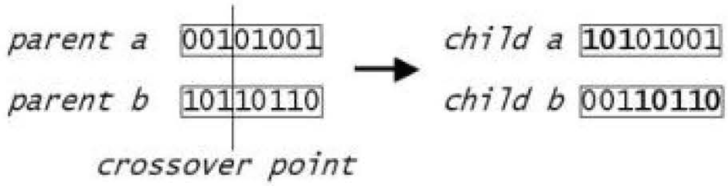

Figure 4: The crossover process (Bräunl, 2008)

2.2 Selection

Parent selection is the task of assigning reproductive opportunities to each individual in the population. There are a number of widely used methods including proportionate selection and tournament selection. The proportionate selection method calculates the probabilities of individuals being selected as proportional to their fitnesses and selects individuals for mating based on this probability distribution. Currently, there are many genetical selection methods being used but the roulette wheel selection method is normally used (see Figure 3).

2.3 Crossover

Crossover is a reproduction technique that takes two parent chromosomes and produces two child chromosomes. In a traditional GA, simple crossover operators such as one-point or two-point crossover are often used. These crossover operators work by randomly generating one or more crossover point(s) and then swapping segments of the two parent strings to produce two child strings (see Figure 4).

2.4 Mutation

Mutation is applied to each child after crossover. The mutation process allows the possibility of introducing new genes in to the population. It works by inverting each bit in the solution with some small probability. Mutation is generally seen as a background operator which provides a small amount of random search (see Figure 5). It also helps to guard against loss of valuable genetic information by reintroducing information lost due to premature convergence and thereby expanding the search space. Bäck (1993) suggested a mutation rate of 1/n as a lower bound on the optimal mutation rate, where n is the length of the chromosome.

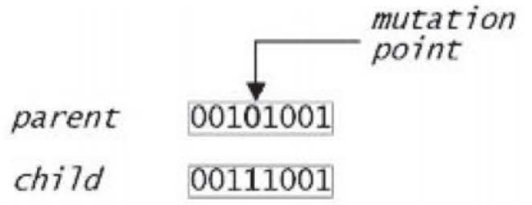

Figure 5.The crossover process. (Bräunl 2008)

3. Post-Processed Kinematic (PPK) Procedures

PPK surveys are similar to RTK procedures, but the base lines are not processed in real-time. PPK involves using one or more roving receivers and at least one reference receiver remaining stationary over a known control point. GPS data are simultaneously collected at the reference and rover receivers. The data are downloaded from the receiver, and the baselines processed using GPS software. When choosing between a kinematic and a static methodology, the GPS surveyor basically is making a choice between productivity and accuracy. There is no doubt that the short sessions of the kinematic procedures can produce the largest number of GPS points in the least amount of time; however, because of the shortened occupation times and less data to resolve integer ambiguity, there is a slight degradation in the accuracy of the work.

4. Experimental Results

4.1 Data Acquisition

The data were collected in static mode using a common observation interval of 1- second data rate and the method is demonstrated in a PPK mode. Every station had very good observing environments since they are each set up on top of a building. For kinematic analysis, the ESRI station is selected as a reference station while the SV01 with a baseline length of approximately 3.8 km, DPT9 with a baseline length of approximately 6.7 km and LAND station with a baseline length of approximately 23.2 km (see Figures 6 and 7). To validate the performance of the proposed method, the data obtained from the SV01, DPT9 and LAND station will be treated as kinematic data set. All data sets were collected by multi-frequency GNSS receivers (Leica viva GS15 and Trimble R10 receivers). Details of stations used in the study are shown in Table 1.

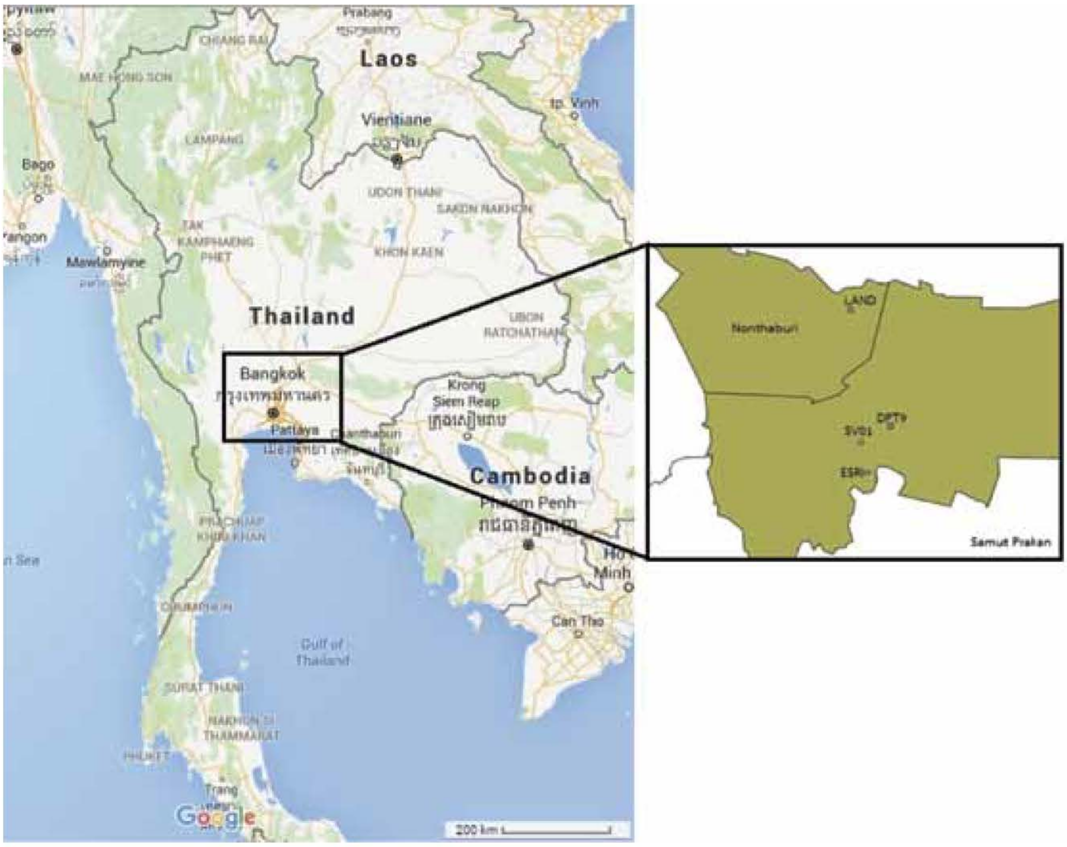

Figure 6: Map of network stations for satellite receivers used in research

Table 1: Details of the station used in the study

STATION	location	Figure of Station.
ESRI	CDG House Building, 202 Nanglinchi Rd, Chongnonsee,Yannawa, Bangkok 10120	
SV01	Salvithan Nithet Building, Department of Survey Engineering, Chulalongkorn University	
DTP9	Department of Public Works and Town & Country Planning Building, 224 Watthanatham Rd., Huai Khwang, Huai Khwang, Bangkok, 10320	
LAND	Survey and Mapping Building, Chaeng Watthana Road, Bang Phut, Pak Kret Nonthaburi, 11120	

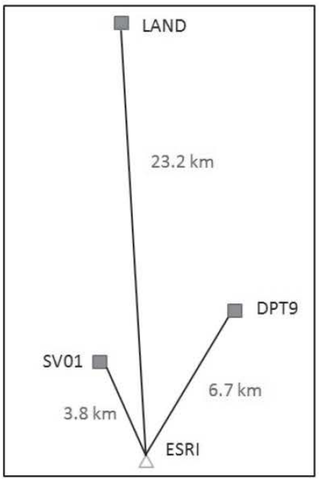

Figure 7: The location of network stations for satellite receivers used in research

4.2 Data Processing

Kinematic data processing was carried out using the RTKLib software (Takasu, 2011). The 24-hr data set was segmented into 1-hr sessions, and hence, a total of 24 sessions were obtained. Each 1-hr session was processed using both the proposed procedure with the Crossover Rate=0.8 and Mutation Rate = 0, 0.005, 0.0075 and 0.01 (with the aid of GA) and the standard procedure (without the aid of GA). The Crossover and Mutation rates used in this experiment were suggested by the previous studies (Srinuadee et al., 2012 and Bäck, 1993). The results obtained from the proposed procedure were compared with the results from the standard procedure to determine the levels of improvement in the number of ambiguity-fixed solutions.

4.3 Results

The levels of improvement in the number of ambiguity-fixed solutions from the proposed procedure were compared with the results from the proposed procedure with the Crossover Rate=0.8 and Mutation Rate = 0, 0.005, 0.0075 and 0.01 (with the aid of GA) and the standard procedure (without the aid of GA) are shown in Table 2. The computation of ambiguity resolution success rate can be referred to Srinuadee and Satirapod (2015).

Table 2: The levels of improvement in the number of ambiguity-fixed solutions from the proposed procedure and standard procedure (varying mutation rate)

Session	SV01 (BL=3.8)					DPT9 (BL=6.7)					LAND (BL=23.2)				
	RTK POST	Mutation Rate				RTK POST	Mutation Rate				RTK POST	Mutation Rate			
		0	0.005	0.0075	0.01		0	0.005	0.0075	0.01		0	0.005	0.0075	0.01
1	884	3551	3520	3551	3551	3427	3600	3600	3600	3600	2720	851	851	851	851
2	3227	3600	3600	3600	3600	2964	3600	3600	3600	3600	205	1523	1523	1523	1523
3	3089	3600	3385	3600	3600	3079	3600	3600	3600	3600	0	2340	2340	2340	2340
4	3045	3600	3593	3600	3600	3435	3600	3600	3600	3600	14	1444	1444	1444	676
5	3272	3600	3383	3600	3600	2310	3599	3600	3600	3600	0	969	969	969	234
6	2200	3600	3314	3600	3600	2986	1946	1946	1946	2482	0	563	698	698	463
7	2387	3546	3524	3546	3546	3135	3446	3446	3446	3446	0	739	1683	173	739
8	2343	3596	3238	3596	3596	3383	3600	3593	3593	3600	0	260	3202	1683	749
9	1895	3397	3471	3600	3397	3555	3514	3600	3600	3390	0	2195	3600	3232	1581
10	2021	3600	3600	3600	3600	3280	3599	3451	3450	3600	0	3600	3587	3593	3010
11	2262	3600	3600	3600	3600	2274	3600	3600	3600	3600	0	3600	3600	3599	3600
12	961	3542	3555	3600	3600	2714	3599	3600	3600	3600	0	3600	3600	3600	3600
13	862	3565	3560	3600	3600	1948	3600	3600	3600	3600	0	3600	3600	3599	3600
14	1968	3594	3565	3600	3600	2200	3599	3599	3599	3600	0	3600	3600	3600	3600
15	763	3596	3600	3599	3600	2200	3600	3600	3600	3600	0	3600	3599	3600	3600
16	3405	3600	3600	3594	3559	1955	3599	3600	3600	3600	372	3600	3600	3600	3600
17	3462	3600	3600	3589	3589	3511	3600	3599	3599	3600	3526	3599	3599	3593	3599
18	2288	3600	3600	3575	3600	3413	3599	3600	3600	3599	3390	3600	3600	3600	3600
19	582	3599	3481	3552	3560	3182	3600	3600	3600	3599	3431	2693	2738	3595	2321
20	1078	3577	3577	3401	3401	3600	3600	3559	3559	3599	3465	1752	1511	940	1535
21	527	3227	2176	2117	3288	3480	3600	3154	2831	3600	3381	3600	3600	1299	3600
22	1194	3064	3108	3189	3139	3510	3600	3600	3600	3600	3600	2374	2331	2655	2635
23	1912	2557	2710	3420	3600	3513	3594	3594	3594	3593	3003	3597	3600	3600	3443
24	1742	2250	1821	2352	2611	3590	3596	3600	3599	3599	3511	1729	2460	1325	2196
%AR	54.83	95.41	92.8	95.7	97.27	84.08	97.79	97.15	96.78	98.27	35.44	68.32	75.12	67.95	65.62

Summary of results obtained from the proposed procedure were compared with the results from the proposed procedure with the Crossover Rate=0.8 and Mutation Rate = 0, 0.005, 0.0075 and 0.01 (with the aid of GA) and the standard procedure (without the aid of GA) is shown in Table 3.

Table 3: Summary of results obtained from the proposed and standard procedures

Station	**baseline length**	**No. of Epoch**	**RTK POST**	**MR=0**	**MR= 0.005**	**MR= 0.0075**	**MR= 0.01**	**Improvement (%)**
SV01	3.8	3600×24 = 86400	41037 (47.50%)	82661 (95.67%)	83331 (96.45%)	82930 (95.98%)	84078 (97.31%)	**48.85%**
DPT9	6.7	3600×24 = 86400	42005 (48.62%)	84789 (98.14%)	84882 (98.24%)	85480 (98.94%)	85956 (99.49%)	**50.08%**
LAND	23.2	3600×24 = 86400	27104 (31.37%)	64688 (74.87%)	54956 (63.61%)	56522 (65.42%)	59376 (68.72%)	**36.79%**

5. Conclusions

In this paper, the concept of genetic algorithm (GA) and its application in GNSS kinematic positioning are presented. The GA has been successfully introduced to the post-processing kinematic mode. A comparison of the levels of improvement in the number of ambiguity-fixed solutions and success rate of ambiguity resolution between the proposed procedure with the Crossover Rate=0.8 and Mutation Rate = 0, 0.005, 0.0075 and 0.01 (with the aid of GA) and the standard procedure (without the aid of GA) is carried out. Overall, the proposed GA-based method can improve the ambiguity resolution rate at 48.85%, 50.08% and 36.79% for the 3.8 km, 6.7 km and 23.2 km baseline lengths respectively. Therefore, the results obtained from the proposed procedure clearly indicate that it can improve the success rate of ambiguity resolution.

References

Bäck, T., 1993, Optimal Mutation Rates in Genetic Search. in: *Proceedings of the Fifth International Conference on Genetic Algorithms*, S. Forrest (ed.) (Morgan Kaufmann, San Mateo,CA): 2-8.

Bräunl, T., 2008, Embedded Robotics: Mobile Robot Design and Applications with Embedded Systems. 3th ed, Springer.

Holland, J. H., 1975, Adaptation in Natural and Artificial Systems. University of Michigan Press.

Sivanandam, S. N. and Deepa, S. N., 2008, Introduction to Genetic Algorithms, Springer-Verlag Berlin Heidelberg.

Srinuandee, P., Satirapod, C., Ogaja, C. and Lee, H., 2012, Optimization of Satellite Combination in Kinematic Positioning Mode with the Aid of Genetic Algorithm. *Artificial Satellites*, Vol. 47, Issue 2, 35-46.

Srinuandee, P. and Satirapod, C., 2015, Use of Genetic Algorithm and Sliding Windows for Optimising Ambiguity Fixing Rate in GPS Kinematic Positioning Mode, *Survey Review*, 47(340), 1-6.

Takasu, T., 2011, RTKLIB Version 2.4.1 Manual http://www.rtklib.com/prog/manual_2.4.1.pdf. [access on 11 April 2016].