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Development and Evaluation of GA-Based Time-of-Day Intervals Optimization Program for Traffic Signal Control

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A Research Project Report

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16. Abstract

Traffic signal control is one of the most cost effective means of improving urban mobility. Signal control can be categorized as pretimed, actuated and adaptive. Among these, both pretimed and coordinated actuated controllers deploy multiple signal timing plans to account for traffic demand changes during a day, while adaptive control changes timing plan in real time according to traffic conditions. In the case of pretimed and coordinated actuated signals, morning peak traffic would differ from than that of off peak to a degree such that it would be better to use two different signal timing plans. Traffic engineers determine such time-of-day (TOD) intervals manually using one or two days worth of traffic data. A few recent studies developed statistical and heuristic methods that develop TOD intervals using archived traffic data. These approaches determine TOD intervals through the minimization of within cluster distance and maximization of between cluster distances. Thus, the clusters do not directly reflect the performance of timing plans and often result in only local optimal TOD intervals.

The report presents a genetic algorithm based method that optimizes TOD intervals with explicit consideration of signal timing performance. The method implements two stage optimizations: outer loop for TOD intervals and inner loop for timing plans of corresponding intervals. An experimental result with a case indicates that the proposed method produces stable TOD intervals and comparable performance. The study also compared the performance of different number of TOD intervals using multiple SimTraffic simulation runs.

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1. INTRODUCTION AND BACKGROUND

Controlling traffic signal timing at an optimal condition is undoubtedly one of the most cost effective means of improving mobility of urban traffic system. As a result, majority of studies related to the signal control have focused on developing better traffic signal timing plans by developing computerized programs including TRANSYT-7F (*1*), Synchro (*2*), PASSER-II (*3*) or better optimization techniques. For example, Park et al. (*4*) developed a genetic algorithm-based signal timing optimization program that simultaneously considers cycle, split, offset, and phase sequences for oversaturated intersections.

As traffic demand changes over time, especially by time-of-day, traffic engineers develop multiple signal timing plans to accommodate these changes over time. For example, signal timing plan deployed in the morning peak would be different from that of midday. This is called time-of-day (TOD) mode control. It is the most common traffic control approach for non-adaptive signals in urban signalized intersections. In addition, traffic signals are coordinated in order to provide better progression along major arterials. Timing plans under TOD intervals are different in nature such that when a new timing plan is implemented over the previous timing plan, the progression bandwidth along an arterial could be damaged, which is known as a transition cost. Thus, the number and the selection of the TOD intervals are as important as finding the optimal signal timing plan for each of the intervals.

In practice, traffic engineers manually collect traffic count data for one or two days, plot the aggregated volumes and determine the TOD intervals based on engineering judgment. This approach may not be efficient since it cannot keep up with the rapid changes in daily traffic. Thus, an adaptive and automated tool that utilizes a large set of archived traffic data and produces an optimal TOD plan could be very useful. This would eliminate the shortcomings of the short-term manual counts and the reliance of the expert judgment.

A recent study proposed the use of statistical clustering algorithms to determine such TOD intervals (*5*). The study results indicated that statistical methods produce fairly good clusters, however, situations arise when “unclean” clusters or isolated clusters are formed. Unlike the majority of the clusters, these isolated clusters do not follow an intuitive TOD scheme. As a result, traffic engineers have to manually assign the adjacent cluster or a special algorithm has to be developed to refine the clusters. Park et al. (*6*) pointed out that “unclean” clusters are inevitable due to the nature of statistical clustering algorithms as they do not include the time-of-day variable. They, then, proposed a heuristic clustering technique on the basis of genetic algorithm that removes such “unclean” clusters and results in comparable performance. They recommended that the proposed heuristic needs to be implemented several times in order to select the most intuitive TOD intervals, since the process occasionally generates illogical TOD intervals.

The objectives of this paper are to develop an automation process that identifies optimal TOD intervals for urban signal systems, and to evaluate the performance of different number of TOD intervals using a microscopic simulation program, SimTraffic.

2. METHODOLOGY

2.1 Data Extractor

The Smart Travel Lab (STL) at University of Virginia developed the Data Extractor to obtain historical traffic volume data from the archived signal system traffic database. Once a user selects detectors (or intersections) and a period, Data Extractor creates a SQL query to extract data from the database. One of the features in Data Extractor is filtering of "bad" data due to either detector malfunction or communication errors.

2.2. Genetic algorithm

Genetic algorithm (GA) is a heuristic search technique based on the mechanics of natural selection and evolution. It works with a population of individuals, each representing a possible solution to a given problem. Each individual obtains a fitness value according to its performance to the problem. The highly fitting individuals are given opportunities to reproduce by mating with other highly fitting individuals in the population. This reproduction creates a new population of possible solutions. Each successive generation contains individuals with higher fitness values than previous generations.

Genetic algorithm uses three basic operators: reproduction, crossover and mutation, although other enhanced operators have been suggested and implemented. The reproduction operator selects individuals with higher fitness, while the crossover operator creates the next population from the intermediate population. The mutation operator is used to explore some areas that have not been searched. More details on genetic algorithm can be found in related literature (*7*). Schema theorem and building blocks hypothesis are rigorous explanations of how genetic algorithm works.

2.3. Genetic algorithm-based optimizations

The flow chart diagram shown in Figure 1 illustrates the Genetic algorithm based process used in this paper. Detail explanations are followed.

2.3.1. Optimization of time of day intervals – outer loop

The outer loop randomly generates a number of (user selects the number) breakpoints. There are 96 possible breakpoints during the day (every 15 minutes). Breakpoints are re-generated if any two falls fewer than two hours apart as it is not practical to change timing plans for less than two hour intervals due to transition costs.

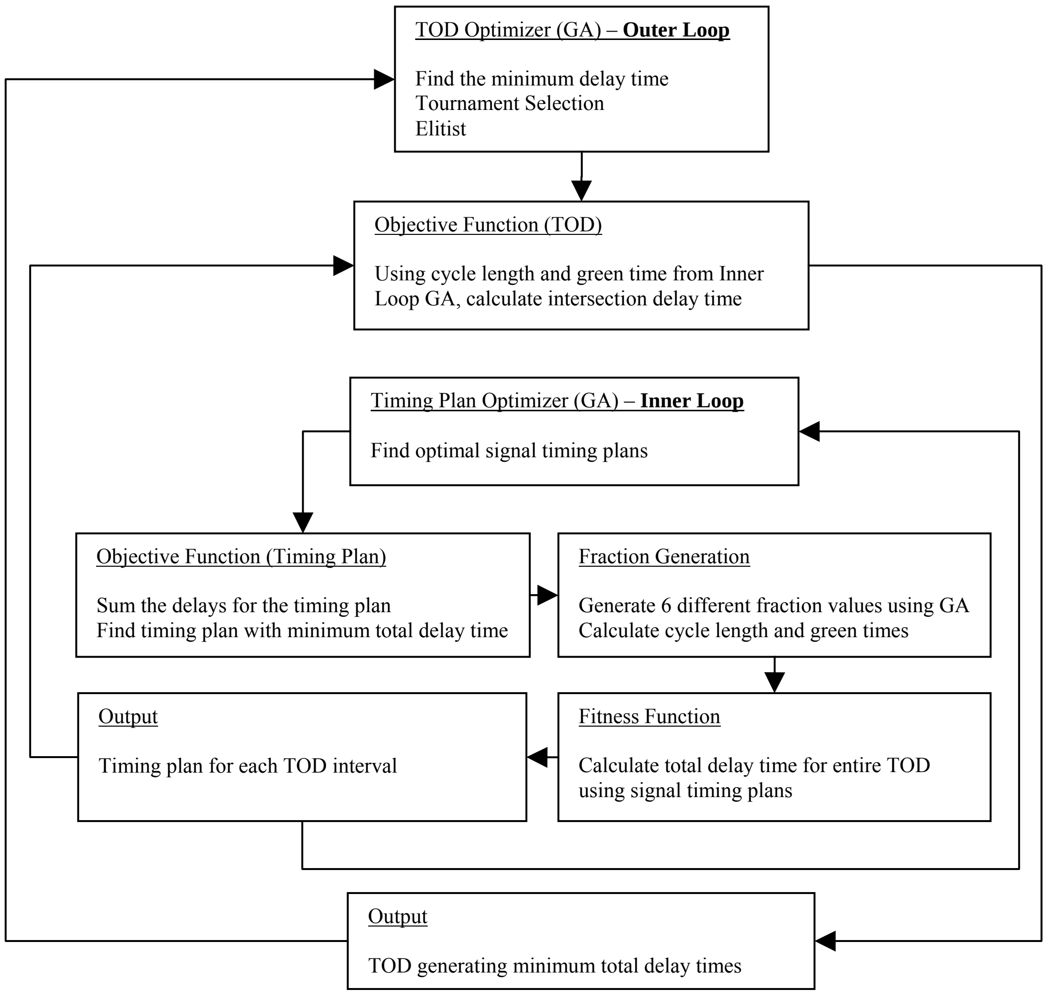

Figure 1. Flowchart of proposed approach

The outer loop, using equation (1), sums each TOD interval's delay time (calculated in the inner loop) for the intersection, then finds the lowest total delay for a set of breakpoints. Additionally, the program utilizes an elitist technique to improve convergence in finding the optimal TOD plan.

$$d = \Sigma_k \, \mathrm{Min}(d_{1,i,j} + d_{2,i,j}) \qquad (1)$$

Where,

- d = total delay time
- d_1 = uniform delay time
- d_2 = incremental delay time
- k = Number of breaks
- i = Number of timing plan optimization iteration (1, 2, 3, ..., 30)
- j = Number of TOD optimization iteration (1, 2, 3, ..., 25)

2.3.2. Optimization of signal timing plans – inner loop

In order to improve convergence of the inner loop GA optimization, TOD timing plans of a representative intersection were optimized. It utilizes randomly generated fractional values to calculate cycle lengths and green times. The inner loop takes these fractions along with the TOD intervals generated by the outer loop and, through the uniform control delay equation (2) and the incremental delay equation (3), calculates the total delay for the particular intersection and TOD interval.

$$d_1 = \frac{0.5 \times C \times (1 - g/C)^2}{1 - \left[\min(1, X) \frac{g}{C} \right]} \tag{2}$$

Where,

d_1 = uniform control delay assuming uniform arrivals (s/veh)
C = cycle length
g = effective green time for lane group (s)
X = v/c ratio or degree of saturation for lane group

$$d_2 = 900T \left[(X - 1) + \sqrt{(X - 1)^2 + \frac{8klX}{cT}} \right] \tag{3}$$

Where,

d_2 = incremental delay to account for effect of random and oversaturation queues, adjusted for duration of analysis period and type of signal control (s/veh)
T = duration of analysis period (h)
k = incremental delay factor that is dependent on controller setting
l = upstream filtering/metering adjustment factor
c = lane group capacity (veh/h)
X = lane group v/c ratio or degree of saturation

2.4. Evaluation

Synchro and SimTraffic are widely used software in transportation research institutions. Synchro produces the optimal signal plan for each TOD by determining appropriate cycle length and green time with a given road capacity and traffic volume. Each individual TOD requires a separate Synchro file. SimTraffic uses these Synchro files and their respective optimal signal plans to run traffic simulations; the simulations output, among other useful information, the total delay time of a given intersection, corridor or network. Using multiple runs, each with different random number seeds, delay times can be compared for various TOD plans.

3. CASE STUDY

3.1. Network and Number of TOD Intervals

Three coordinated actuated signalized intersections on the Reston Parkway in Fairfax, VA were used for the case study. The cross streets are New Dominion Parkway, Bluemont Way, and Sunset Hills Road; this network is shown in Figure 2. This subsection of the Reston Parkway was selected for the quality of its traffic detectors and high traffic volume.

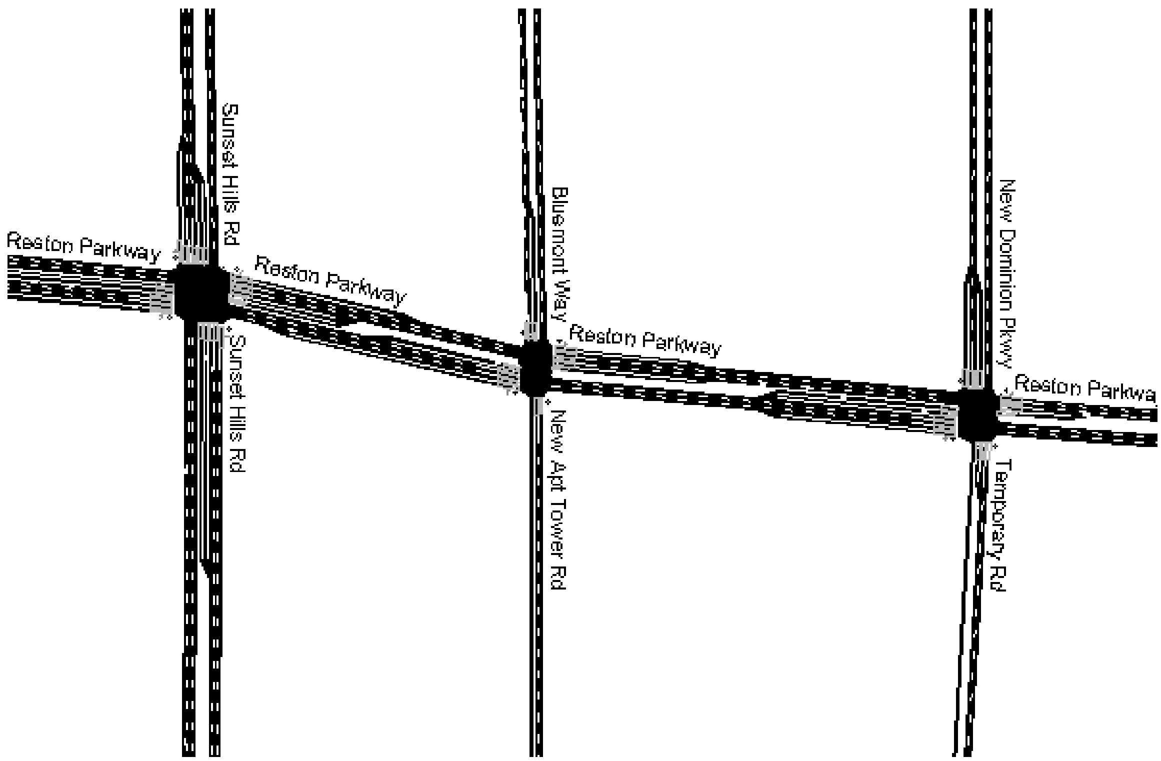

Figure 2. Test network in Fairfax, VA

The current time of day signal timing plan uses 5 intervals. In this study, a series of TOD intervals ranging from 4 to 8 are developed through the proposed approach and evaluated through SimTraffic microscopic simulation program.

3.2. Data reduction

<u>Data Extractor</u>

The Data Extractor was used to extract traffic volumes for the three intersections for weekdays between December 12, 2001 and June 12, 2002. These volumes consisted of traffic counts for every 15-minute period, with 96 intervals daily. The Data Extractor screened these volumes for possible erroneous data. Since the detectors did not cover all the particular phases for each intersection, turning ratios calculated from VDOT Synchro files were used to estimate the individual phase volumes. A total of 133 days of traffic data are utilized in the study.

Input to GA

The inner loop GA optimizer used the 90th percentile volume data for a representative intersection, the Sunset Hills Road intersection. The data used were divided for each of the intersection's bounds: north, south, east and west. This intersection has better quality detectors as well as higher traffic volumes than the other two intersections; the 90th percentile was used as to simultaneously eliminate both high outliers and data comparable to SimTraffic and Synchro preferable data. Saturation flow rates and turning ratios, used to calculate volume and capacities for the lane groups at the intersection, were obtained from the Synchro files provided by the Virginia Department of Transportation (VDOT).

Input to evaluation

Synchro used 90th percentile volumes to generate optimal signal timing plans for the three intersections. Unlike the inner loop GA optimizer input data, these volumes were for all three intersections, and split for each phase (i.e., North Bound Left, East Bound Thru, etc.). SimTraffic used the Synchro files provided by the VDOT for the parameters used to run the simulations.

3.3. Genetic Algorithm Optimizations

3.3.1. Outer loop setting

The outer loop GA, (the TOD finder) used a population size of 20 and maximum generation of 40 during GA optimization. It also used both replication and crossover operators, as well as a mutation with a probability of 0.03. Selection and crossover were based on the tournament selection and uniform crossover. The objective function used in the outer loop GA was the total delay time calculated from equation (1).

The outer loop GA used a candidate array (full of possible breakpoints) with the size of 20 (number of candidates) by 96. Each of these members relate to every 15-minute periods, as discussed earlier. A random number between 0 and 1 was assigned to each member array. For each candidate, the N highest numbers out of 96 (actually 94 since the 1st and 96th are ineligible) were selected to represent breakpoints. N is the user-desired number of breakpoints for the outer loop GA run. These breakpoints are used in the inner loop GA run to calculate intersection delay times. After the inner loop GA ran, this outer loop GA summed the total delays for each TOD. The program then output the breakpoints in time format. The elitist method, which transfers the best solution to the next generation, is utilized.

3.3.2. Inner loop setting

The inner loop GA used a population size of 20 as well, but the there were only 20 generations used for this optimization. This used both replication and crossover operators, as well as using a mutation probability of 0.03.

As discussed earlier, the inner loop generates and finds the optimal timing plans for each of TOD interval determined from outer loop GA. The inner loop GA optimizes traffic signal timing plan on the basis of HCM delay equation.

Instead of producing individual traffic signal parameters separately, fractional values were used to prorate available green times of each phase. For an intersection, the random number generator generated six fractional values in binary codes. The binary codes were in the range of 8 digits. Fractional value f_1 was used to calculate the cycle length. Since all the activities in an intersection share the same cycle length, a fraction and a remainder of the fraction can be used to split the cycle length. F_2 divided the cycle length into the main-street and cross-street phase. In addition, f3 through f6 determined the green times of the eight phases different phases. Using these cycle length and green times, the delay time was calculated through the objective function.

This step-by-step example pertains to Park's earlier publication (*4*). This procedure was conducted for every individual TOD signal timing plan optimization.

<u>Fraction Generation and Decoding</u>

$\{f_1; f_2; f_3; f_4, f_5; f_6\} = \{10110101;11011110;00110011;01010101;10101010;11001001\}$

$\{10110101\}_2 = \{45\}_{10}$: $f_1 = 181 / 255 = 0.71$

The first step for determining signal timing plan is to obtain cycle length. Cycle length between minimum and maximum cycle lengths is calculated as follow:

$$\text{Cycle} = \text{MinC} + \text{INT}[(\text{MaxC} - \text{MinC}) \times f_1] \quad (4)$$

Where, MinC = minimum cycle length, and
MaxC = maximum cycle length

Green times are calculated from the equations shown below.

$$\text{Green}_{\varphi 1} = mp1 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times f_2] \times f_3\} \quad (5)$$
$$\text{Green}_{\varphi 2} = mp2 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times f_2] \times (1 - f_3)\} \quad (6)$$
$$\text{Green}_{\varphi 3} = mp1 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times (1 - f_2)] \times f_4\} \quad (7)$$
$$\text{Green}_{\varphi 4} = mp2 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times (1 - f_2)] \times (1 - f_4)\} \quad (8)$$
$$\text{Green}_{\varphi 5} = mp1 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times f_2] \times f_5\} \quad (9)$$
$$\text{Green}_{\varphi 6} = mp2 + \text{INT}\{[(\text{Cycle} - \text{MP}) \times f_2] \times (1 - f_5)\} \quad (10)$$

$$\text{Green}_{\varphi 7} = \text{mp1} + \text{INT}\{[(\text{Cycle} - \text{MP}) \times (1 - f_2)] \times f_6\} \quad (11)$$

$$\text{Green}_{\varphi 8} = \text{mp2} + \text{INT}\{[(\text{Cycle} - \text{MP}) \times (1 - f_2)] \times (1 - f_6)\} \quad (12)$$

Where, MP = sum of minimum phase time,
mp1 = minimum phase time for left-turn phase, and
mp2 = minimum phase time for through movement.

Then, the delay time is calculated for a TOD by inserting values of cycle length and green time using the equation (1) and (2).

3.4. Synchro Optimization

In order to make the most realistic simulation, the TOD plan was used to create optimal timing plans in Synchro. Synchro used the corresponding volume data to create the signal timing plans. For example, for the seven breakpoints, for the first TOD, volumes between 12:30 AM and 4:45 AM were used. Synchro was instructed to use the peak hourly volume for this interval to create the timing plans. Then each intersection had its splits and cycles optimized. Finally, the cycle and offset for the entire network were optimized. It is noted that the phase sequence was not optimized as it could violate drivers' expectations. The timing plans for each TOD and breakpoint set were then output to a column delimitated text file for use in SimTraffic runs.

3.5. SimTraffic Evaluation

SimTraffic can only evaluate a maximum of 19 intervals, none being over 2 hours long. For comparable results, each of the breakpoints generated for all the different number of TOD intervals were also used for SimTraffic interval breakpoints. The simulation ran from 6:00 AM to 8:45 PM in order to incorporate the highest traffic volumes and to address the limitations of 19 maximum intervals. The timing plans generated by Synchro were input to the corresponding times according to the GA generated breakpoints.

Ten trial simulations were run for each breakpoint set, and all trials ran with a different random number seed. One of SimTraffic simulation parameters is "random number seed"; the user can either specify a number, or use zero so that SimTraffic will randomly select a seed value. The seed used in this evaluation was zero, so that the numbers would be randomly generated and the trial runs would have different results. The SimTraffic simulation runs provide a variety of measures of effectiveness (MOEs) such as total fuel used and total stops, total delay time, and total travel time.

Since this simulation evaluated the effect of changing timing plans, the method that SimTraffic uses to transition from one plan to another must be discussed. When timing plans change, first the new timing plan is loaded, and then a cycle clock is calculated based on current phase start times and durations. The simulation controller will either increase or decrease phase times, depending whether or not the calculated clock is ahead by more or less than half of a cycle of the target (new timing plan) cycle clock. This will increase the process of coordination of the intersections, but if these changes do not affect the cycle lengths quickly enough, the transition will then increase green times. The transition is complete when the calculated cycle clock is less than a certain percentage behind the target clock cycle.

4. EXPERIMENTAL RESULTS AND ANALYSIS

4.1 Convergence of GA-based optimizers

The objective function values of average and best solution at each generation were plotted. The elitist method ensured that the best solution of the current generation transfers to the next generation. As shown in Figure 3, the most significant improvement of the objective function value occurred within only eight generations. However, in order to provide the TOD optimizer more chance to search for a better solution, 40 generations were used.

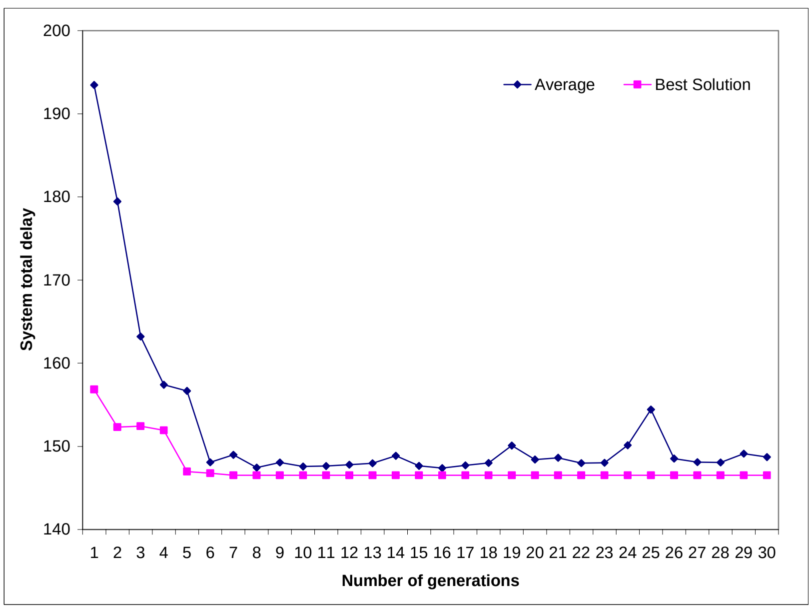

Figure 3. Convergence of GA TOD optimizer – Outer Loop

On the other hand, as shown in Figure 4, the inner loop GA optimizer converges nearly immediately, at the second generation. Still, to allow the optimizer to search for the best solution, 20 generations were used in this optimization. These plots also confirmed that the GA-based optimizer was actively searching the minimum delay time and the fitness values were converging to the minimum delay time.

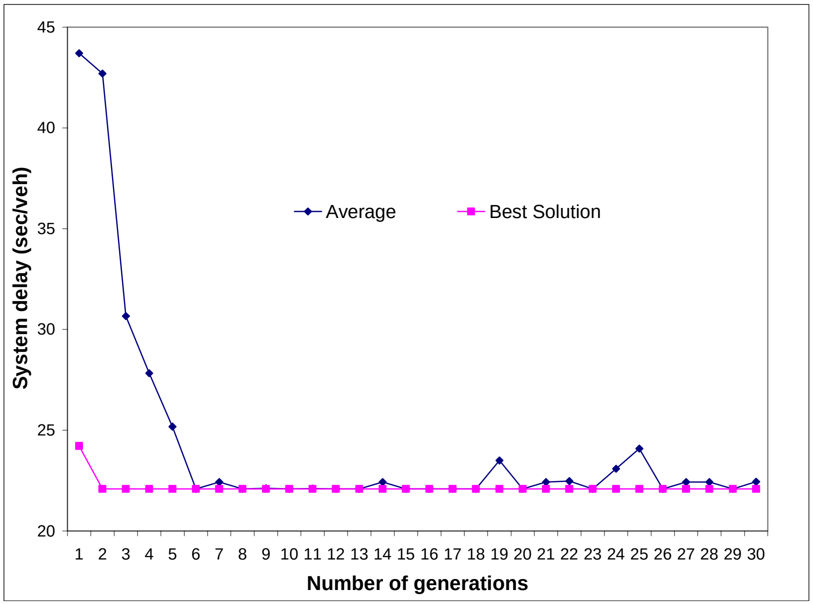

Figure 4. Convergence of GA signal timing optimizer – Inner Loop

4.2 Experimental Results

The GA TOD finder program outputs both the breakpoints and the fractional data used for the traffic parameters required by the delay equations (2, 3). Cycle length's output, for example, for the eight breakpoint set ranged for 100 seconds (the minimum) for off peak, through midday to 110 seconds for PM peak, to 105 seconds for PM off peak. Table 1 gives an example set (from four breakpoints) of green splits for the four break point plan.

Table 1. Signal timing plans under four TOD intervals – GA TOD finder output

	TOD PLANS			
	OFF PEAK	AM PEAK	MID DAY	PM PEAK
North Bound Left	10	10	10	10
North Bound Thru	40	40	40	40
South Bound Left	10	10	10	10
South Bound Thru	40	40	40	40
West Bound Left	10	10	13	19
West Bound Thru	40	40	42	41
East Bound Left	10	10	13	19
East Bound Thru	40	40	42	41
Cycle Time	100	100	105	110

The GA TOD finder program was run five times, each with a different number of breakpoints and the breakpoints for the corresponding number desired for analysis are shown in Table 2. These breakpoints roughly correspond to areas of lower volume, which is logical, as changing timing plans at peak volume times brings a higher transition cost, and thus higher delay times.

Table 2. GA TOD finder program generated TOD plans

Number of Breakpoints					
4	**5**	**6**	**7**	**8**	**Current (5)**
6:45 AM	6:00 AM	4:00 AM	1:45 AM	12:30 AM	6:30 AM
11:15 AM	10:00 AM	7:45 AM	4:00 AM	4:45 AM	9:30 AM
4:00 PM	3:45 PM	10:15 AM	7:30 AM	7:00 AM	3:00 PM
7:45 PM	7:15 PM	3:45 PM	10:15 AM	9:30 AM	7:30 PM
	10:45 PM	5:45 PM	3:45 PM	2:45 PM	10:00 PM
		9:15 PM	6:30 PM	5:00 PM	
			8:45 PM	7:00 PM	
				9:30 PM	

SimTraffic generated MOEs for each simulation run. Table 3 provides the averages for each of these runs. A T-test was prepared in order to see the actual difference between the differing numbers of breakpoints. The point of comparison was the five-breakpoint GA output, as this is the normal number of breakpoints. According to the T-test, which determines if there is significant difference between the total delay means for the plans, six break points gives a significantly different total delay than the normal five breakpoints. This is at the 95% confidence level. The six-breakpoint TOD plan is plotted against the corresponding volumes in Figure 5.

Table 3. SimTraffic simulation results on the GA TOD finder generated TOD intervals

	Number of Breakpoints				
	4	**5**	**6**	**7**	**8**
Vehs Entered	103,069	103,020	103,602	103,294	103,388
Vehs Exited	102,593	102,525	103,114	102,788	102,896
Starting Vehs	70	70	64	64	72
Ending Vehs	546	565	552	570	563
Travel Distance (mi)	133,997	133,952	134,701	134,277	134,376
Travel Time (hr)	36,151	36,503	33,504	35,196	34,590
Total Delay (hr)	32,281	32,635	29,619	31,320	30,711
Total Stops	239,774	240,276	242,798	241,256	244,735
Fuel Used (gal)	23,478	23,619	22,260	23,042	22,759
T-test*	0.39		0.02	0.17	0.06

* Probability total delay different than 5 break points'

Note: average of 10 SimTraffic runs are shown.

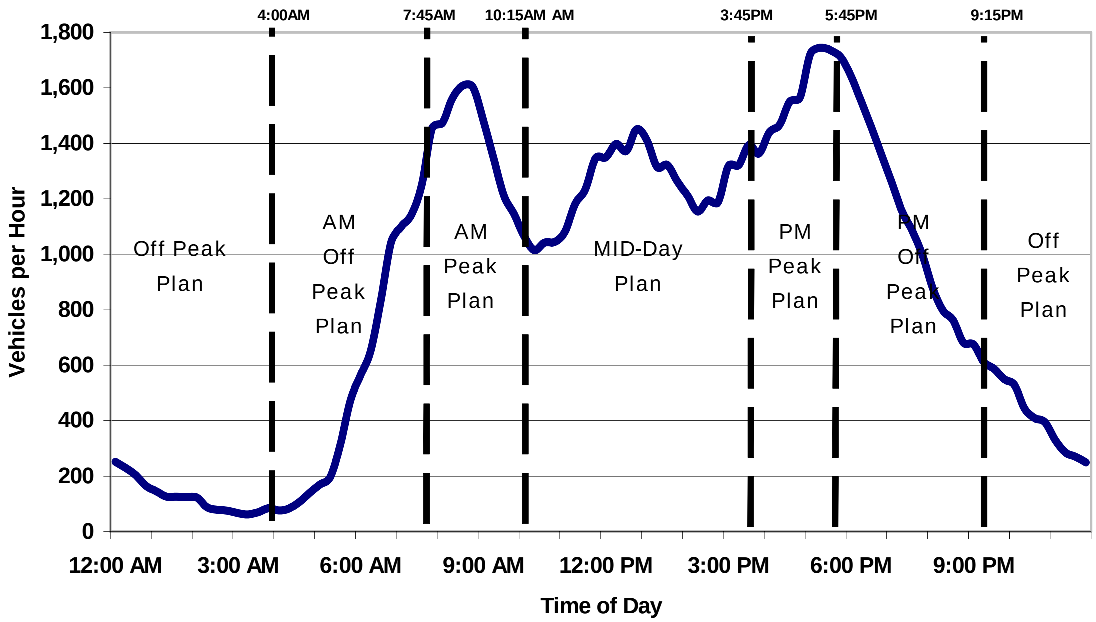

Figure 5. Four Breakpoints TOD Plan and Daily Volume

5. Conclusions and Future Research

The GA TOD finder program produces suitable and realistic breakpoints from archived traffic data. Furthermore, the SimTraffic simulation results illustrate that six breakpoints is the best.

From these results, one can conclude that the GA TOD finder program is an effective way to automate finding optimal TOD breakpoints. This automation could make traffic signals more responsive to seasonal changes in traffic volume patterns. This automation would also reduce resources employed by local traffic agencies to find optimum TOD plans.

Currently, the traffic engineers spend a great deal of time and effort in data collection; they utilize statistical tools to recognize traffic patterns, interpretation to produce a timing plan, and simulation to evaluate the results. The GA TOD finder program processes the data extraction, pattern recognition, and evaluation all at once. Therefore, it can improve cost vs. benefit efficiency by cutting down on amount of resources and time required.

Several issues need to be addressed, however. First, there is an issue of data collection. Many intersections do not have traffic detectors installed, and some of these installed detectors are malfunctioning. The program would be best used where there is accurate, archived data for time periods available. In addition, Synchro files required for the analysis are not always available for all intersections. Secondly, the short cycle lengths output by the program illustrates that more congested intersections would provide more accurate and representative results. Additionally, simulations using more intersections, possibly the whole corridor, might give different results. Changing TOD plans has more of an impact with more intersections involved, as each intersection needs to be coordinated with each other.

In summary, using genetic algorithms to minimize total delay time is an effective way to automate creating time of day plans for intersections with considerable seasonal changes in traffic volume.

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APPENDIX

User Guide for TOD Finder Program: GA Xtractor

September 2003

Developed by
Smart Travel Lab, University of Virginia

Introduction

The Time-of-Day (TOD) signal control system is the most used approach in non-adaptive signal control systems. The TOD control groups the time intervals with similar traffic patterns, and develops the timing plan according to the intervals like in the plot above (AM, Mid, PM, and Off). The optimal break points for the TOD signal control should minimize the transition cost and maximize the traffic flow.

Currently, the designing of a TOD signal control system involves a traffic volume data collection effort, expert interpretation of traffic patterns, and the use of optimization support tools. As a result, the whole process is very expensive and time-consuming that it cannot be performed as much as it is needed. In addition, the design cannot account rapid change in its consideration, and the signal system may not operate at peak efficiency. Thus, an automated and adaptive application that can support the design a TOD signal control system is needed.

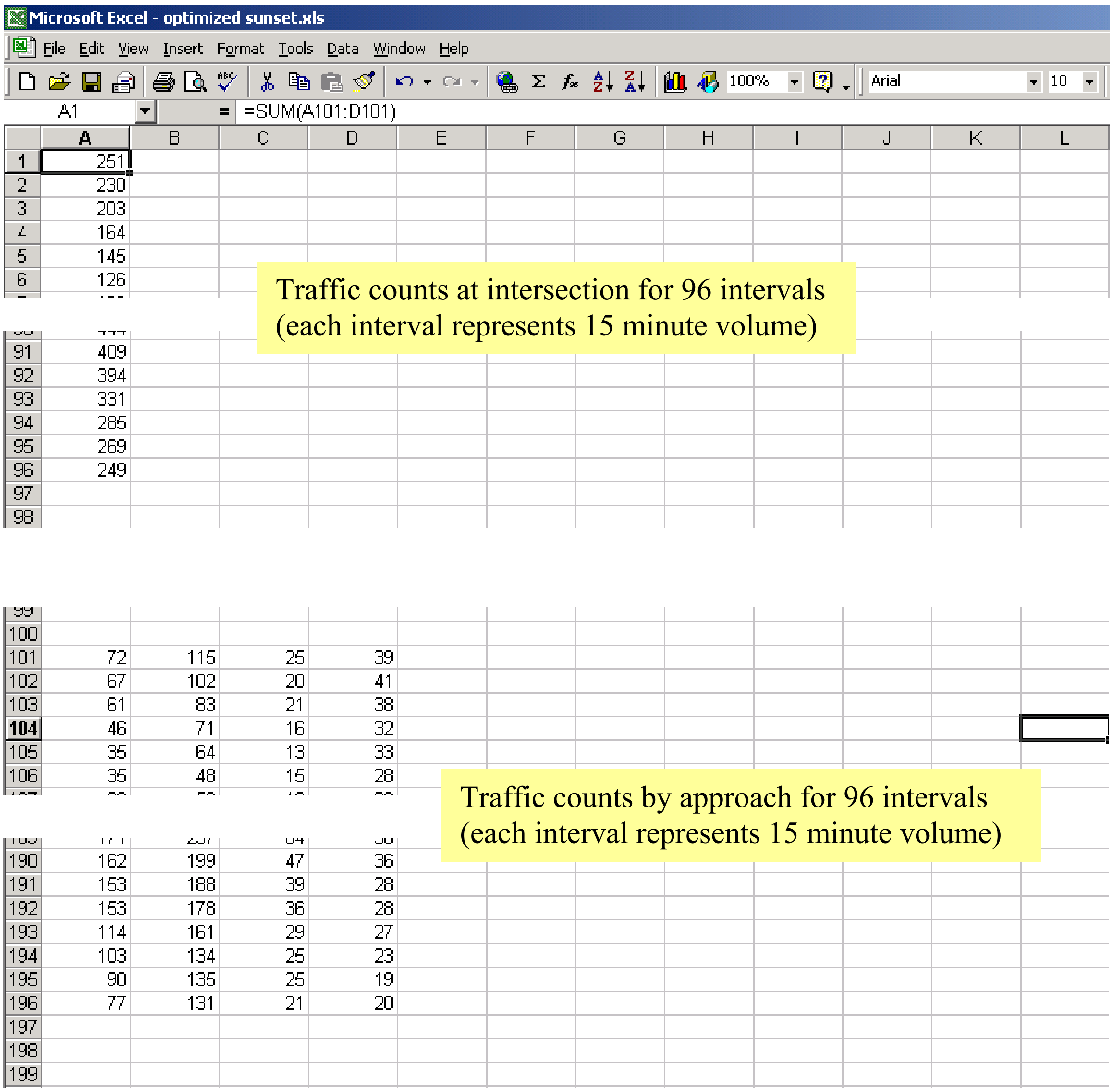
GA Xtractor is written in Visual Basic. The GA-based approach directly finds TOD break points and evaluates the performance of resulting clusters. This user guide conducts one case for users to follow the application through. The case is for “Reston Pkwy- Sunset Hills”

Step One: Obtain Volume Counts

1. Obtain volume counts for every 15 minute period, try to use 90 percentile counts taken from sources, whether it is hand counts or archived database.

2. Compile data into an excel file. Rows 1 through 96 should have combined for total intersection data, while rows 101 to 196 have four columns of data, with North, South, East, West data.

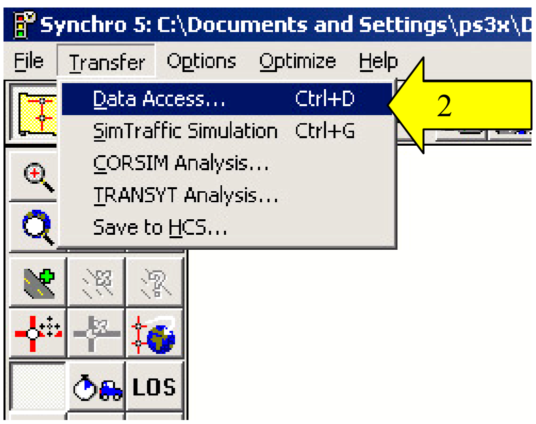
An example MicroSoft Excel file:

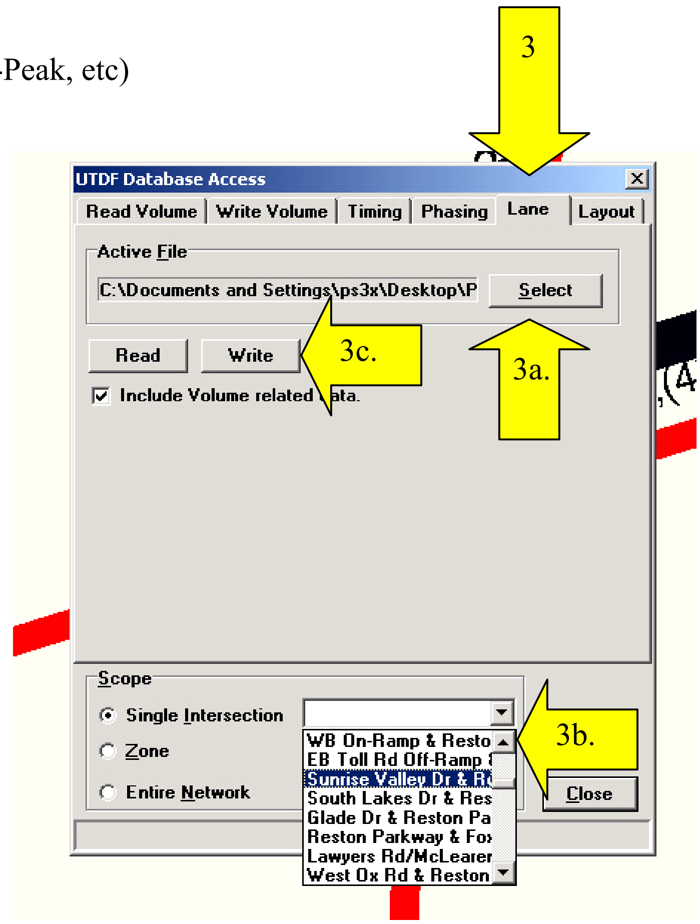


	A	B	C	D
1	251			
2	230			
3	203			
4	164			
5	145			
6	126			
91	409			
92	394			
93	331			
94	285			
95	269			
96	249			
97				
98				
100				
101	72	115	25	39
102	67	102	20	41
103	61	83	21	38
104	46	71	16	32
105	35	64	13	33
106	35	48	15	28
190	162	199	47	36
191	153	188	39	28
192	153	178	36	28
193	114	161	29	27
194	103	134	25	23
195	90	135	25	19
196	77	131	21	20
197				
198				
199				

Step Two: Extract saturated flow rates and turning ratios from Synchro input file

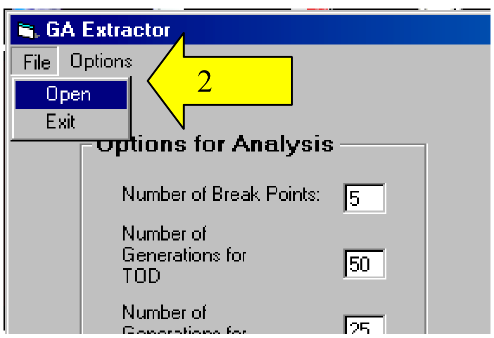
1. Open Synchro with the corresponding file for the intersection
2. Go to Transfer menu, and select “Data Access”
3. In the opening window, select the “Lane” tab,
    a. Make sure the file type is a comma delimited file (*.csv),
    b. Select the desired intersection, and
    c. Click “write”
4. Repeat for each TOD interval (e.g. AM, OFF-Peak, etc)

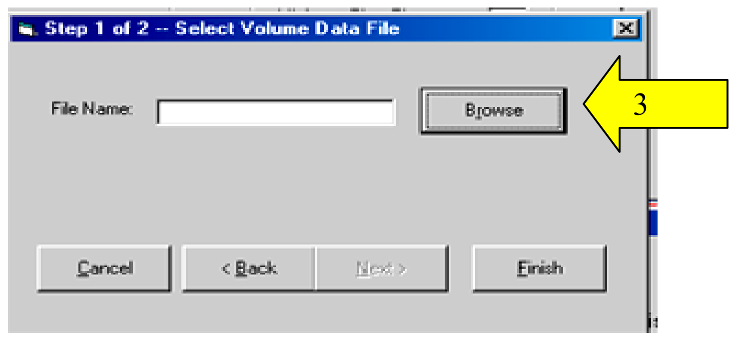


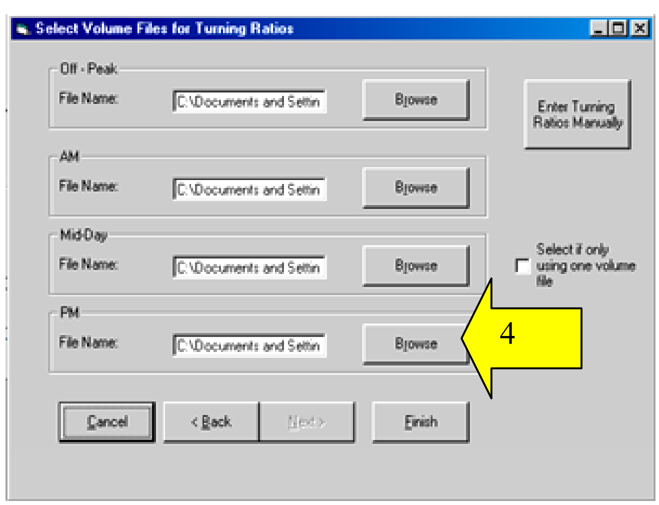


Step Three: Open Data Files in GA Xtractor

1. Open GA Xtractor
2. Select "File" menu, and select "Open"
3. In new window, select excel file created in Step One
4. Select the .csv files for each TOD. Indicate if you have only one .csv file for input. Also if one has no .csv files output from synchro, one can manually input turning ratios and saturated flow rates

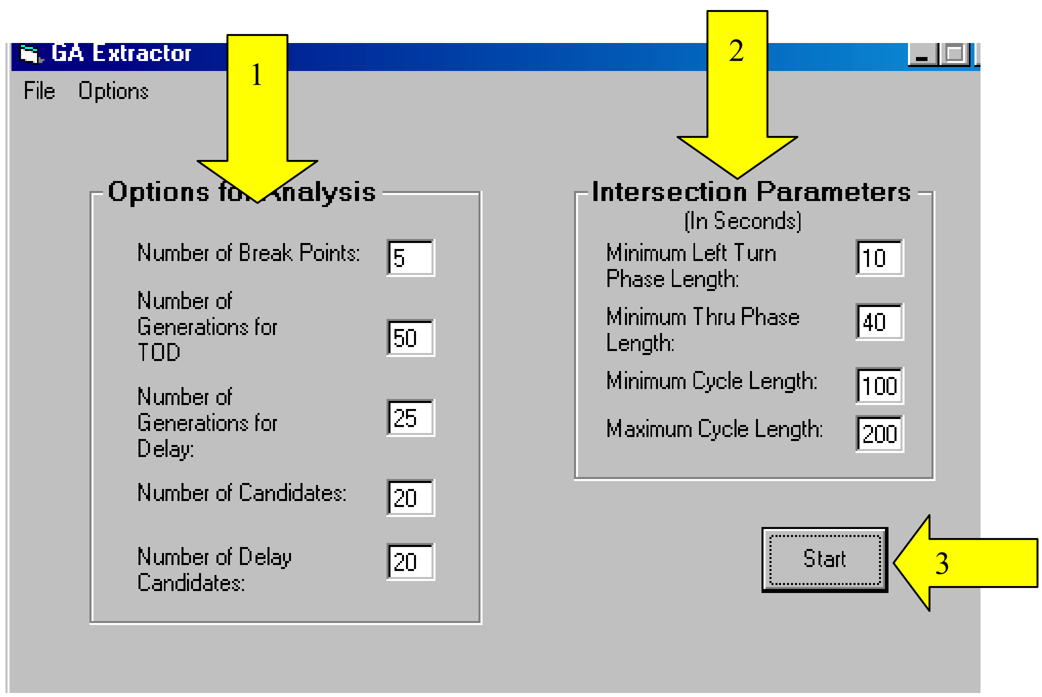






Step Five: Running analysis

1. Enter specifications for analysis:
    a. Break Points: Determines number of TOD intervals
    b. Generations/Candidates for TOD/Delay: Determines how often the program cycles through the possible TOD plans/ break point sets
2. Enter specifications for Intersection:
    a. Phase/Cycle Lengths: Information should be taken from Synchro files
3. Click Start, progress bar should appear showing progression of analysis



Step Six: Reviewing Output

1. Dialog box will appear when analysis is complete.
2. In the excel file's directory, two text files with the filename format of [excel filename]plot.txt and [excelfilename]delay.txt are created.
3. File of importance is plot file, shown below
4. Important information in plot:
   a. Break points both in graphical format and in time format:
   b. Volume counts for every fifteen minutes for entire intersection