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River Trip Optimization Scheduling Based on Artificial Intelligence Simulation and the Bee-Swarm Genetic Algorithm

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Abstract: The study on the impacts of human activities on natural resources is of critical importance in constructing effective management strategies in rafting trips. The Camping Schedule Intelligent Generator (CSIG), the computer program developed in the study, which successfully models the complex, dynamic human-environment interactions in the rafting river. This generator includes two parts: artificial intelligence simulation and BSGA-based Optimization. It employs artificial intelligence in creating an individual-based modeling system. With the help of BSGA, this simulation system successfully models the recreatinal rafting behavior and captures the decision making of rafting trips as they responsively seek to optimize their functions. After modeling, the paper applys CSIG to the Colorado River, which is a famous rafting river and find that: the numbers of short motor-trips (6-8 day) and long-oar trips (15-18 day) are obviously larger than the other two. Finally, the study analyzes the sensitivity of the model and finds that when the water velocity varies in the actual range.

Keywords: Agent-based modeling, BSGA, human-environment interactions simulation, individual-based models

INTRODUCTION

As people's living standard improves, river rafting is becoming more and more popular among the public. With the rise in popularity of river rafting, trip schedule for river has been not able to meet the rapid demand of the public. As we all know, duration and propulsion varies from trip to trip, which directly lead to the complexity of the schedule. Thus, an interesting problem is left for the responsible government agency: how to develop the best schedule and determine the carrying capacity of a river. So far, many people have done a lot of scientific studies and surveys about river trip schedule.

The value of simulation methods as a tool for understanding and managing river trip scheduling is evident. The Wilderness Area Simulation Model was developed in 1972 by Resources for the Future with programming assistance from IBM, which was a useful tool for establishing the relationship between use levels and encounters and testing management alternatives (Wagtendonk, 2004). Recent application of simulation modeling to wilderness and river settings has revived interest in the Wilderness Simulation Model was first developed by Smith and Krutilla (1976). It was stimulated by ideas expressed by Stankey (1972) in a book on the theoretical and applied analysis of natural environments (Krutilla, 1972). In a study published (Cesario, 1975), described a simulation modeling approach that utilized GPSS (General Purpose Systems Simulator) (Cesario, 1975). Then, the Wilderness Use Simulation Model (WUSM), developed by Shechter and Lucus (1978) to estimate the numbers of encounters and potential conflicts among parties, was subsequently adapted for application to rafting parties on the Colorado River by Underhill and Xaba (1983), Underhill *et al*. (1986) and Borkan and Underhill (1989). A number of artificial intelligence techniques combined with Geographic Information System (GIS) functions were employed by many of these simulation modeling efforts to address human-environment interactions (Green, 1987; Ball, 1994; Slothower *et al.*, 1996; Gimblett *et al*., 1996, b; Briggs *et al.*, 1996). The Grand Canyon River Trip Simulator project (GCRTSim) is one component of the most recent round of sponsored research intended to assist park managers in updating the CRMP (Bieri and Roberts, 2000; Gimblett *et al.*, 2000; Hall and Shelby, 2000; Jalbert, 1993; O.Brien and Roberts, 2000; Roberts and Gimblett, 2001). Cole (2005) compiled information about recent progress in the application of computer simulation modeling to planning and management of recreation use, particularly in parks and wilderness and give a report.

Whitewater trips along the Colorado River through the Grand Canyon National Park are an excellent example of our issue. Underhill *et al*. (1986) adapted the

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wilderness use simulation model for application to the Colorado River. Underhill and associates (Underhill and Xaba, 1983; Borkan, 1986; Underhill *et al*., 1986; Borkan and Underhill, 1989) adapted the original WUSM model for application to rafting parties on the Colorado River. The effects of launch schedules and variable water flows were major input components of the river trip model is the guiding document that sets limits on recreational use within the park. The initial Grand Canyon river trip model is no longer in use and the Park is still in need of better means for evaluating alternative trip schedules (Jalbert, 1993; Roberts and Gimblett, 2001) proposed a project to collect and analyze data from recreational rafting users on the Colorado River within the Grand Canyon National Park (Kaplinski *et al*., 2003) proposed a consistent, comprehensive and long-term approach to assessment and monitoring of camp sites and visitor capacity is needed. In recent years, how to design the schedule of the trip become a problem of optimal schedule. Rafael *et al*. (2009) solved heuristically in real situations with optimal schedule (Rafael *et al.*, 2009; Fang *et al*., 2011) proposed a multi-objective approach to schedule joint participation of multiple individuals (Fang *et al*., 2011).

In this study, we assumed a" Big Long River" which has the same characteristics with the true world rafting river. Firstly, the paper studies the characteristic of the trips of varying duration and propulsion. Then we propose a model to schedule an optimal mix of trips by using artificial intelligence simulation and the Bee-Swarm Genetic Algorithm (BSGA). Finally, we have a case study of the Colorado River in US and make a comparison between the schedule we get and the original trip schedule of the Grand Canyon.

THE BASIC INDEX OF MODEL

The goal of this study is to simulate a realistic river environment and predict the possible outcomes of changes to the current set of regulations. Camping schedule was influenced by various basic indexes: the river environment, boat speed, camping schedule and the metrix of an optimal schedule. All of these efforts informed the development of an artificially intelligent and statistical-based computer simulation model of rafting traffic along the "Big Long River".

Creating the "Big Long River" environment: To create this river environment, we divided the "Big Long River" corridor (M miles) into m-miles cell and identified the locations of sites along the" Big Long River" corridor. Thus, the number of site is M/m. Sites in our model are classified into camp site Y and activity site W [(Y + W = (M/m)] and appropriate attributes of sites can get from data statistics (Catherine *et al*., 2002).

Camp sites CS_k, which can provide passengers with not only camping but also scenic views, distribute fairly uniformly throughout the big Long River" corridor. But no two sets of campers can occupy the same site at the same time. The camp sites for accommodation should be planned in advance, while for camp sites for entertainment, trips will decide whether to visit or not according to their attractive degree. Activity sites AS_k can provide passengers with scenic views but no accommodation. Trips will also decide whether to visit or not according to their attractive degree. As for the key sites with special attractiveness, trips can choose to visit it even though other trips have already occupied the site.

Boat speed: Boat speed here is defined as the sum of the flow velocity of the big Long River" v_w (which is based on the instantaneous water flow rate governed by water releases at the big Long River") and the speed of the boat (propelled by motor or oar). Since the river is downstream and its velocity direction is the same as the forward direction of the boats. In our study, we assume that the flow velocity of every segment of the big Long River is the same. Therefore, the velocity of oar-powered rubber rafts v_{oar} and the velocity of motorized boats v_{motor} can be expressed respectively as follows:

$$\begin{cases} V_{oar} = v_{water(date)} + v_{oar} \\ V_{motor} = v_{water(date)} + v_{motor} \end{cases} \tag{1}$$

where, the measure unit of the velocity is *mph*, $v_{water(date)}$ represents the average flow velocity of the river in a day, v_{oar} represents the velocity of oar-powered rubber rafts and v_{motor} represents the velocity of motorized boat.

Camping schedule: The schedule of a trip is mainly determined by the trip leader. In fact, the trip leader has been allocated before the trip starts. Likewise, the trip agent class has been confirmed. Different agent class own different natures, for this reason, we use L_j (j = 1, 2, ... X) to represent the nature of one trip. A camping schedule mainly consists of two parts: one is launch schedule and the other is daily plan. We intend to construct a stochastic simulation function: L_j (LS_j, SS_j), among which LS_j stands for the launch schedule of L_j, while SS_j stands for the daily plan of L_j.

Metrics of an optimal schedule: The main standard of an optimal schedule is: allowing as many trips as possible to travel down the" Big Long River" on the premise of ensuring the passenger satisfaction. And the study defines the optimal schedule from two aspects: trip amount and passenger satisfaction.

The trip amount *X*: As the number of the passengers constantly increases, park managers need to adjust the six-month schedule to allow more trips to travel down the big

Long River". Hence, the larger the trip amount X is, the more desirable the mix of trips will be. Next part, we will make a prediction on the value of X.

Passenger satisfaction: The passenger satisfaction is also a standard to measure the mix of trips. It is mainly determined by three factors: minimal contact with other groups, enough time to enjoy scenic views and high quality and attractiveness of the sites and thus:

$$\overline{H_j} = \omega_A \overline{H_{Aj}} + \omega_B \overline{H_{Bj}} + \omega_c \overline{H_{cj}} \qquad (2)$$

where, ω_A, ω_B and ω_c, respectively represents the weights of the following three satisfactions:

Wilderness enjoyment: H_{A_j} means the minimal contact with other groups of boats on the river. We take the number of occasions when the j^{th} trip sharing site with other trips as our measure standard. Moreover, the bigger the number of occasions of site sharing is, the lower the average passenger satisfaction of the wilderness enjoyment will be.

Scenic views enjoyment: H_{B_j} is mainly presented in the form of the time for trips to stop to enjoy scenic views and recreational activities. Too little scenic views enjoyment will lead to not enough time for passenger to relax. Too much time will have an impact on the time for exciting white water rapids enjoyment. In conclusion, the closer to the time regulated in the agreement, the more ideal the scenic views enjoyment is.

Site quality enjoyment: H_{C_j} Site quality enjoyment is mainly presented in the form of the average attractiveness of the site sequence for the j^{th} trip to stop. And it can be reflected by the statistics of the previous population of passengers. The higher quality the site has, the more attractive it will be.

SIMULATION ALGORITHMS

In addition to the simulation and discussion about the physical river itself, we also simulate the decision making of guides, which means the camping schedule, with artificial intelligence.

The launch schedules LS_j simulation: Launch schedule $LS_j\,(T_{0j}, N_j, V_j, t_{a_i}, g_j, A(CS_1(G_1),CS_2(G_2)...CS_{Nj}(G_k)))$ is an important indicator to form the nature of the trip leader L_j (j = 1, 2 ...X). This nature is influenced by the factors in the following six major aspects: departure time, T_{0j} the length of duration for a river trip N_j (j = 1, 2, ..., X), the speed of the trip V_j, the time for sight-seeing and recreation t_{aj}, which is clearly regulated in the passenger agreement between passenger and the park, the sequence of target camp site $A(CS_1(G_1), CS_2(G_2), ..., CS_{Nj}(G_k))$ and the trip scale that the j^{th} trip needs to consider g_i . In addition, only when $gi \le Gi$, the j^{th} trip will camp in CS_i. Then we consider applying the model of arranging sequence by computer stochastic simulation to ensure that: all passengers being able to safely live in suitable camp site every night on the "Big Long River"; all passengers being able to safely arrive at the destination on time; time for scenic views being ensured. Then, the whole process can satisfy the following artificial intelligence algorithm:

Step 1: Randomly extract from LS_j (T_{0j}, N_j, V_j, t_a) and number it with LS_1 (T_{0j}, N_j, V_j, t_{a1})

Step 2: Calculate the maximum displacement $S_{max(date)}$ that trip L_j can travel every day.
In order to ensure the passengers safety in the trip, a sunset function is needed to determine the earliest and latest time to select a camp. According to our regulation, passengers must arrive at the target camping 4 h before the sunset. And when the trip arrives at the target camping, there will be no more movement along the river on that day. Instead, it is the time for rest and entertainment in the target camping. The measure unit of the time of arriving CS_{N_j} (Catherine *et al*., 2002) is uniformly expressed by hour (h). Based on the length of every day $t_{day(date)}$ and the speed of the trip V_j, the maximum displacement $S_{max(date)}$ that the trip can travel every day will be:

$$s_{max(date)} = (t_{day(date)} - t_{a(date)} - 4) \times V_j \qquad (3)$$

where, $t_{a(date)}$ represents the allocated time for scenic views enjoyment every day.

Step 3: Determine the target camping: $A(CS_1(G_1), CS_2(G_2)$ ... $CS_{N\,j}$ $(G_k))$ of LS_1 of every day:

For the purpose of ensuring the successful implement of the schedule, we get that the smaller the distance from the target camping to the maximum displacement is, the more ideal the schedule will be. Therefore, when, $S_{CS_{N_j-1}} < S_{CS_{N_j}} \le S_{\max(date)}$ we can find the $\max\left|S_{CS\,N\,j}(G_k)\right|(G_k \ge g_k)$ by the filtering of computer. Repeatedly executing step 2 and step 3, we can finally determine the sequence of the target camping $A(CS_1(G_1), CS_2(G_2)$ ... $CS_{N_1}(G_k))$ in the LS_1 camping.

Step 4: The confirmation of the subsequent schedule LS_j (T_{0j}, N_j, V_j, t_{a_j}, g_i, $A(CS_1(G_1)$, $CS_2(G_2)$ ... $CS_{N\,j}$ $(G_k)))$

1st: Randomly generate the subsequent schedule $LS_j+1(T_{0j+1},N_{j+1}, V_{j+1},t_a)$

2nd: Repeatedly execute the step 2 and step 3 and determine the hypothetical sequence of the target camping $A'\left(CS_1(G_1), CS_2(G_2)\cdots CS_{N_1}(G_k)\right)(1<j\le X)$ of the subsequent schedule LS_j.

3rd: Check respectively whether N_j of the target camping in LS_j have been occupied by other trips. If the answer is no, then we can get $A = A'\left(CS_1(G_1), CS_2(G_2)\cdots CS_{N_1}\cdots(G_k)\right)$ $(1< j \le X)$ If the answer is yes, record the array of occupied target camping $O(CS_m(G_k))$. Under the condition of ensuring the passengers exiting the river on time, owning enough time for scenic views, entertainment as well as sleeping, the control range of every site is $range\left(CS_{N_j}(G_j)\right)$.

4th: Determine the new sequence of the substituted site $O'\left(CS_m(G)\right)$ in the $range\left(CS_{N_j}\right)$, targeting at $\max\left|S_{CS_{N_j}}(G_k)\right|(G_k \ge g_k)$. If no applicable sequence of the substituted site $O'\left(CS_m(G_k)\right)$ can be found in the $range\left(CS_{N_j}(G_j)\right)$, terminate LS_j (T_{0j}, N_j, V_j, t_{a_j}, g_i. Go back to 1st and regenerate a new LS_j (T_{0j}, N_j, V_j, t_a, g_i. If the sequence $A'\left(CS_1(G_k), CS_2(G_k)\cdots CS_{Nj}(G_k)\right)$ $(1<j\le X)$ wh ich is successfully replaced, is the sequence A. Then since the experienced trip leaders are bound to timely adjust the daily schedule, the replacement of the target camp site will not affect the schedule of the subsequent sites. The launching number of the trip into the" Big Long River" is $X = X + 1$ ($X \ge 1$).

Step 5: Output X and calculate the added trip amount of the schedule, comparing to the original schedule, which can be expressed as: $a = X - X_o$, where, X_o represent the trip amount that the original schedule can accommodate.

The daily plan SS_j simulation: Daily plan function SS_j (g_i, A_j ($S_1(G_1)$, $S_2(G_2)$, $S_3(G_3)$...)) is a kind of hybrid approach involving expert knowledge, intelligent agents, fuzzy logic, statistical analysis, autocorrelation and other techniques. It can simulate the behavior of choosing passing site to visit by imitating the process of the trip L_j in the reality and get the sequence of the activity site A_j ($S_1(G_1)$, $S_2(G_2)$, $S_3(G_3)$...). Based on that, the passenger satisfaction H_j brought by L_j can be figured out. And the process for trip leader to choose activity sites should satisfy following steps:

Step 1: Define a range of cells within which the trip can engage in activities this would be between the current cell and the target camp cell and then obtain the list of all attraction sites in that range. According to the agreement, confirm the key site from a range of sites.

Step 2: Selecting the site to visit by using the following selection algorithm in Fig. 1.

When a trip reaches a new site, it should check whether its remaining time. If not, the trip can move ahad, or it should further check whether the site is camp site or not. If it is a camp site, then the trip should follow the right part of the Fig. 1; if not, it should follow the travel process in the left part of the Fig. 1.

Then, as the trip continues, when the trip reaches a new site, it should restart the process in the Fig. 1.

where, $A_j(S_1(G_1)$, $S_2(G_2)$, $S_3(G_3)$...) represents the sequence of the activity sites, t_{aj} +4N_j represents the total time spent in activity sites, m represents the amount of the activity sites, which are shared with other trips.

Step 3: Based on function (3) and the output of the sequence of the activity sites $A_j(S_1(G_1)$, $S_2(G_2)$, $S_3(G_3)$...), the total time spent in activity site t_{aj}, the amount of the activity sites which are shared with other trips m and we can account the passenger satisfaction of the trip H_j brought by the schedule $_{SSj}$.

Solution of the optimal schedule based on the Bee-Swarm Gentic Algorithm (BSGA): As the simulation system above is complicated and huge, in order to pick up the computing speed and escape a local optimum, the study adopts a modified genetic algorithm basing on the mechanism of natural honeybee's reproduction evolution-Bee-Swarm Genetic Algorithm (BSGA) (Zhang *et al.*, 2009) to figure out the optimal trip schedule. This algorithm can be used to accelerate the process of the global optimization efficiently and achieve a comparatively better result in continuous optimization and complex optimization.

Application of BSGA to the artificial intelligence simulation: At first, we make use of the artificial intelligence simulation model and figure out some feasible solutions to the schedule. Based on the requirement on the passenger satisfaction and trip amount, it selects some comparatively better solutions. On the basis of some mechanism of BSGA, such as crossover and mutation, we make a little modification to the BSGA, which is combined with the specific circumstances of our model. At last, we figure out the optimal solution of our model.

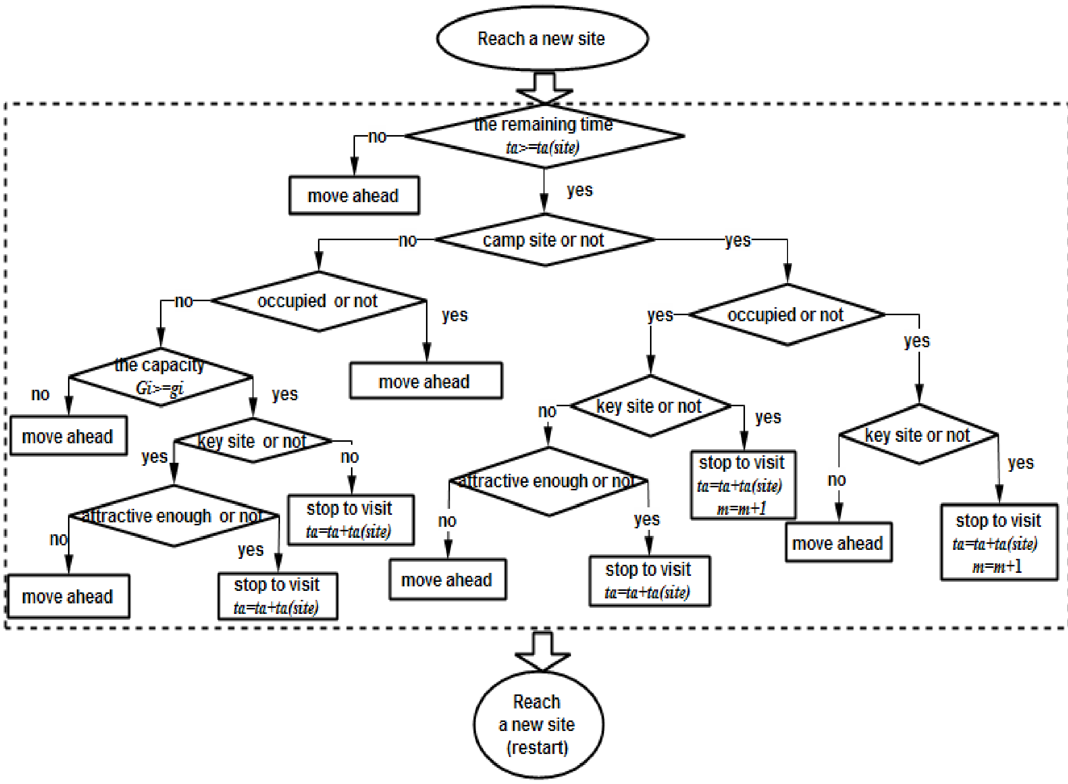

Fig. 1: Decide the sites to visit

Step 1: Generate feasible solutions: The artificial intelligence simulation model can randomly generate A sets of feasible solutions Ω, every set of feasible solutions is composed of the number, type and specific camping schedule of the trips which are launched into the" Big Long River" at every moment. We divided a day into four units, then the trips can be presented as: $\Omega = L_1L_2 \ldots L_T \ldots L_{(183\times4-1)}\, L_{(183\times4)}$, namely, every set of feasible solutions is a feasible schedule to solve the daily trip arrangement in six months.

Step 2: Generate swarm and different kinds of bees: Firstly, figure out average value $\overline{H}$ of the passenger satisfaction $\overline{H_j}$ ($j = 1, 2, \ldots, X$) of all the trips among every set of feasible solutions $\Omega = L_1L_2 \ldots L_T \ldots L_{(183\times4-1)}\, L_{(183\times4)}$, produced by step 1, namely:

$$\overline{H} = \frac{1}{X}\sum_{j=1}^{X}\overline{H_j} \tag{4}$$

If $\overline{H} < H_{limit}$, eliminate this set of solutions. Then, filter the A sets of feasible solutions Ω randomaly generated and select out A_1 sets of feasible solutions with relatively higher satisfaction.

Sort the largest trip amounts $X_n(n = 1, 2, 3, \ldots, A' - 1, A_1)$, which are figured out from every set of feasible solutions Ω, from the biggest to the smallest. Select the first A_2solutions as comparatively better solutions and reserve them, then eliminate the rest. The reserved A_2 sets of feasible solutions can form a swarm. Among them, drones have $c$individuals and the worker population has M_2 individuals. The two populations are generated randomly. The best one as queen, whose value of X is the biggest, is selected from the worker population. The value of X is the fitness of every bee.

From the process of simulation in 5.3, it is easy to find out that, $\Omega_n = R_1R_2 \ldots R_T \ldots R_{(183\times4-1)}R_{(183\times4)}$, ($n = 1, 2 \ldots, A_2$) is the individual chromosome and the schedule characteristic of every trip among the feasible solutions R_t is the gene of this chromosome.

Step 3: Mating between queen bee and drones: Due to the high fitness of the queen bee and drones, the probability of their crossover is very high.

Consequently, it is easy for this excellent model to be reserved. However, it is also easily to be caught in a local optimum. Thus, the BSGA add the crossover operator in order to achieve these three goals: reduce the randomness of the searching; promote the uniformly distribution of individuals; offer chance of survival to the individual with low fitness but great potential. The specific crossover operator include crossover in adaptive rate P_{man} and crossover frequency c, the formula for this is (Zhang *et al*., 2009):

$$\begin{cases} P_{man} = \dfrac{f(x)}{\sum_{i=1}^{N} f_i(x)} + \beta_0 \\ c = l(1 - P_{man}) \end{cases} \quad (5)$$

where, $f(x)$ is the fitness of the current individuals in the swarm namely $f(x) = X$,1, l is the length of chromosome, β_0 is the minimum value of crossover in adaptive rate.

According to the definition formula of the crossover in adaptive rate and crossover frequency (5), queen bee and drones choose proper gene locus to mate. After a crossover, every queen bee and drone will produce a male offspring and a female offspring.

Step 4: Adaptive mutation of offspring of drone and worker bee: Since the order of different trips in of different moment in the feasible solutions Ω can't be altered arbitrarily, the schedule of the trip in latter moment will be influenced by the type of the trip schedule in the former moment. Then, when we substitute the new offspring into the artificial intelligence simulation model to work out the fitness, every gene on the chromosome except for the unchanged gene in the head will go through mutation (Even though they may be genes belonging to the original chromosome, once the gene in the head is replaced, then this gene will mutate.)

Firstly, for the offspring, if no launching boat is arranged at the moment $j-k$, then check the circumstance at the moment $j-k+1$; if launching boat is arranged at the moment $j-k$, then follow the original schedule and input the duration for scenic views enjoyment $N_{j-k,}$ which starts from the site following the schedule $L'_{j=k}$ and the speed of the boat V_{j-k} into the artificial intelligence simulation model. If the schedule for accommodation can be acquired when inputting $N_{j-k}V_{j-k}$, record this schedule. If not, continuously randomly generate new duration for scenic views enjoyment and speed of the boat until the new set can acquire the feasible solution. If the no feasible schedule can be acquired in the mutation, change the arrangement for this moment into no launching trip. Continue to check the circumstance at the moment $j-k+1$, then the offspring of drones and worker bees will respectively change into:

$$\begin{cases} Wor\text{ker } population: R_1 R_2 \cdots R_{T-(k+1)} R''_{T-k} \cdots \\ R''_{T-1} R''_T R''_{T+1} \cdots R''_{T-k} R''_{T+(k+1)} \cdots R''_{(183\times4-1)} R''_{(183\times4)} \\ Drones: R'_1 R'_2 \cdots R'_{T+(k+1)} R''_{T-k} \cdots \\ R'''_{T-1} R'''_T R'''_{T+1} \cdots R'''_{T+k} R'''_{T+(k+1)} \cdots R'''_{(183\times4-1)} L'''_{(183\times4)} \end{cases} \quad (6)$$

Step 5: Recombination of the swarm: By tournament selection, both drones and worker bees recombine their offspring generation and parental generation into *M* new worker bee swarms and *N* new drone swarms. Then compare the worker bee swarm with highest fitness to the original queen bee. If the fitness of the worker bee swarm is higher that of the queen bee, reserve the worker bee swarm; if not, reserve the queen bee.

Step 6: If the algorithm terminated conditions which are shown in formula (7) are not met, go to Step 3, otherwise, the queen bee is output as a global optimal and algorithm terminates:

$$Fitness_{now} > Fitness_{limit} \quad (7)$$

APPLICATION OF THE COLORADO RIVER

The Colorado River runs through Grand Canyon National Park in Arizona for 255 miles from Lees Ferry in Utah to Diamond Creek in Arizona. Visitors to there can enjoy scenic views and exciting white water rapids. The most exciting entertainment is camping along the Colorado River. So, we apply our model, which was built for the" Big Long River", to the Colorado River.

- **Data:** After a study of relative literatures and websites, we find that the time internal for camping activities in the Colorado River is from April 20th to October 20th. After a research on these 6 months, we obtain a series of data:
- **Site classification:** Trip itineraries from 1984 for oar boats and motorboats were based on actual frequencies of use for the 199 river segments, 110 activity sites and 141 camp sites, which means Y = 141, W = 110, m = 0.9 *miles*

- **Water velocity:** Will vary with wet season and dry season. During the time internal for camping activities, the water velocity in different month is different: April-Ma v_{water} = 24.66 *mph*, while June-September v_{water} = 10.96 *mph*.
- **Boat velocity:** Water velocity will vary with the type of boat. v_{oar} = 4 *mph*, v_{motor} = 8 *mph*.
- **The length of duration:** The length of duration will vary with the trip. According the reaserch we get the duration of different trips:

  $N_{Oar}-short = 10day$, $N_{Oar}-long = 10\ day$,
  $N_{motor}-short = 6day$, $N_{motor}-long = 14\ day$,

- **Attraction site statistics:** We make a statistics on comprehensive level of the Top 20 sites in both wet season and dry season, then we obtain the Top 20 attraction site on the attractiveness list (Catherine *et al.*, 2002):
- **Camp site:** Base on some statistics on relative websites, we obtain the Top 23 camp sites, which can accommodate the largest number of passengers (Catherine *et al.*, 2002).
- **The length of the daytime:** From the statistical results of the GAISMA, we get the data of the length of the daytime in the Grand Canyon National Park from April to September.
- **The parameters of the BSGA:** We give the value of the parameters in the BSGA: l = 1844 = 732, β_0 = 0.2, S_{limit} = 0.7, $Fitness_{limit}$ = 150

RESULTS AND ANALYSIS

Combined with the Matlab computer programming, we can get the amount of the mix of four trips launched every day by using artificial intelligence simulation and the bee-swarm genetic algorithm, the results can be found in Fig. 2 and 3:

Seen from the Fig. 2, we can find that when we arrange launching trip in the first day, no trip will be launched in the next day. This is because the amount of the camp sites with suitable capacity is limited. The trips launched in the former day will occupy the limited camp site, resulting in the trips on the river not being able to circulate. That means the increase of the camp sites with suitable capacity will bring the increase of the trips launched. Meanwhile, we also find that, the largest amount of trip launched concentrated in the period from May to September, exactly the wet season of the Colorado River.

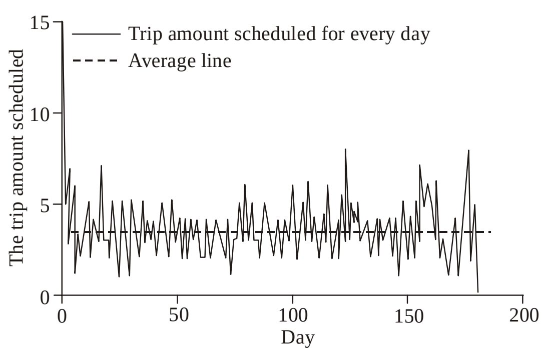

Fig. 2: The amount of trips launched every day in our schedule

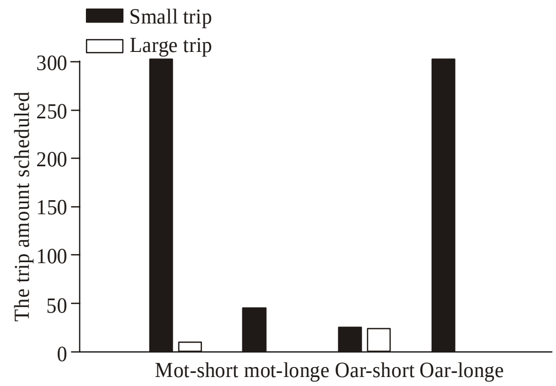

Fig. 3: The amount of various trips launched every day in our schedule

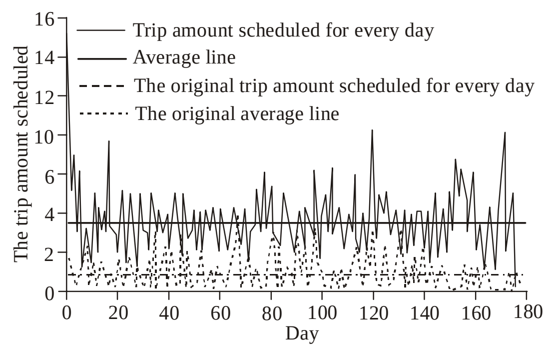

Fig. 4: The total trip amount launched every day of the original schedule and our current schedule

In Fig. 3, the launching amounts of the oar-long trips and motor-short trips are comparatively large. For oar-short trips, the major reason is that oar boats run slow with short trip time. As a result, time for scenic views and entertainment has to be sacrificed to ensure the trip arrangement, resulting in the low passenger satisfaction in the process of camping. For motor-long trips, the main reason is that motor boats run fast with long trip time. In other words, enough sites can be visited to ensure high passengers satisfaction, but long time spent in the site will lead to the traffic jam on the Colorado River. Thus, the amount of these two kinds of trips is smaller.

Schedule evaluation: We make a comparison between the schedule we get through simulation optimization with the original schedule of the Colorado River from two aspects:

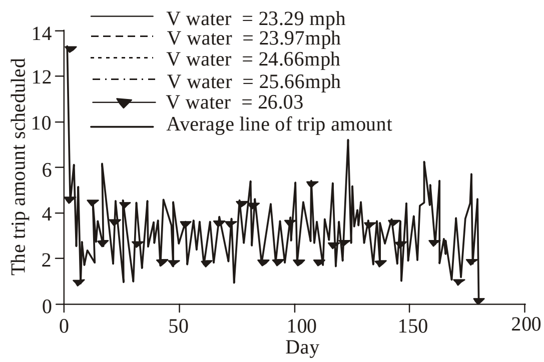

Fig. 5: The parameter space study of the model when water velocity takes varies discretely

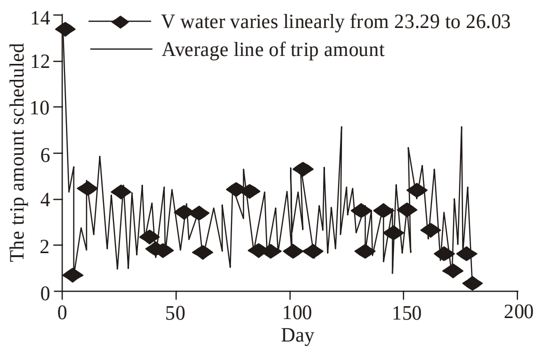

Fig. 6: The parameter space study of the model when the water velocity varies linearly

Trip capacity *X* and satisfaction $\overline{S_j}$:

Trip capacity X: By statistics and surveys, the curve of the change in trip amount launched every day of the original schedule and our current schedule are presented in Fig. 4.

After a comparison between the two curves, we find that the trends of these two curves are almost the same, which can demonstrate that our schedule can satisfy the demand in the reality. The result of this comparison is: the amount of the trip launched during the six months in our schedule is X_w = 631 and 3.4481, while the amount of the trip launched during the 6 months in original schedule is X_o = 138 average and the average amount of the trip launched per day is 0.7. Through our algorithm, we get that 493 more boat trips could be added to the Colorado River's rafting season. Therefore, our schedule has obvious advantages on the utilization of the camp site.

Satisfaction $\overline{S_j}$ **:** The study calculate the average passenger satisfactions of the original schedule as well as our schedule and by comparison, we find that the average passenger satisfaction of the original schedule is 0.7, comparatively higher than ours. In fact, the increase of the launching trip amount will increase the probability of sharing sites with other trips. As a result, the passenger satisfaction will decrease. However, the average passenger satisfaction of our schedule is $0.6185 \geq 0.6$, the basic satisfaction requirement. Thus, our schedule can also satisfy the passengers' requirement.

Parameter space study: A good setting of parameters can greatly enhance the accuracy of the model and improve the efficiency in handing cases. Therefore we inquire into the effect of changes to our model's parameters and whether the effects are what we have expected.

To achieve this goal, we vary the water velocity in our model. In the case study of our model, we search out that the water velocity of the Colorado River in different seasons are of different ranges of value. Based on that, we adopt the midpoint to calculate. But, in reality, the water velocity is continuously changing. So in order to check the robustness of our model in the actual situation, this study launches the following discussion. The results are shown in Fig. 5.

- Firstly, the study talks about the circumstance when water velocity takes different constant values in the range of variation (Fig. 5). Analyzing the result of the former case study, we can get that: the higher the water velocity is, the larger the launching trip amount *X* will be. But among different water velocity within varying ranges of different months, both the trend-line and the average-line of X are very close to each other.
- Then, the study has a discussion about the condition that water velocity varies linearly (Fig. 6). We make a comparison of the average trip amount per day between the situation when water velocity varies linearly and the situation when the water velocity take the average value and find the fact that the average-lines under these two conditions are almost coincident. Although there is some crossover of the two trend-lines, they are similar to each other.

All in all, based on the analysis above, we can draw a conclusion: with the varying range of water velocity in different months, the result of our model owns robustness and the value of *X* that we get from the model is stable. Moreover, it has high feasibility in research of the water area in the reality.

CONCLUSION

The Camping Schedule Intelligent Generator (CSIG) is an optimal camping schedule based on artificial intelligence simulation and bee-swarm genetic algorithm. It can get a schedule that can achieve a goal allowing 181 trips to launch into the Colorado River in six month as well as ensuring the passenger satisfaction, which also means 43 more trips can be allowed in comparison to the original schedule. After the study, the study finds reducing the number of short-oar trips and long-motor trips launched into the big Long River will improve the utilization ratio of the camp site, ensuring more trips can enter river. At the same time, increasing the launching number of camp sites with large capacity in the big Long River can bring the increase of the rate for trips to enter the Big Long River

The CSIG has several following key strengths. Firstly, the model contains no arbitrary parameters. In other words, most aspects of the model are determined simply by value observed in literatures and database about Colorado River. Then, the model is developed from the actual demand of the river managers. By comprehensive consideration of the various problems that we may come across in the actual schedule of the camping, our model vividly simulates the circumstance of scheduling in reality. It can meet the actual demand of the river manager. Finally, the model is of practical significance. The successfully adoption of the Bee-Swarm Genetic Algorithm (BSGA) ensures our model to figure out the optimal schedule in relatively short time and escape a local optimum.

In the future, the CSIG can be improved in the following aspects: firstly, the study assumes the camps and the activities sites are distributed fairly uniformly throughout the river corridor. But it is not true for the reality. Therefore, in the further study, people can have a research on the distribution of the sites and get the optimal mix of trips that is more practical. Secondly, the bee-swarm genetic algorithm can be further improved. In order to improve the accuracy of the result and increase the speed of computing, we can further consider adjusting the elimination principle of the offspring and get the optimal solution with higher efficiency. Finally, people can also have a discussion on the division of the segments of the river and obtain a simulation schedule that is closer to the real condition of the river.

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