Stochastic Modeling and Concurrent Simulation of the Game of Golf

Sungroh Yoon, Seil Lee, and Seong-Jun Oh

ABSTRACT—We propose a novel simulation method for modeling the game of golf using SystemC, a system description language that allows modeling of a concurrent system's behavior. Utilizing the proposed simulator, we compare different outing formats of golf, namely, regular and shotgun, in terms of playing time. Our simulation results reveal that the shotgun format can take longer than the regular format if the number of groups in a golf course exceeds 33 for the scenario we tested, confirming the belief that the shotgun format can take longer than the regular format. We also justify our simulation by comparing the simulation and analytical results.

Keywords—Golf, concurrency, simulation, queuing model.

I. Introduction

A new paradigm for sports research is to adopt quantitative methodologies in natural sciences and engineering. This has opened a new door for analyzing complex behaviors among players and teams. Traditional simulation frameworks based on a single thread exist [1], but they often lack the ability to model concurrent and complex interplay. We use SystemC, a system description language developed for transactional and behavioral modeling of electronic systems [2]. To demonstrate the effectiveness of our approach, we present our results on testing the proposed framework with the game of golf. The insight and techniques obtained from this study will be helpful for IT domains such as computer engineering, where exploring design space is often difficult without realistic simulation of alternative scenarios, that is, the number of processing cores and how to interconnect them.

As recreational golf is usually played by a group (typically foursome), the statistical analysis of golf has focused on the operations by foursomes. An individual golfer's psychology and competency in a foursome was considered in [3], and fair formations of foursomes considering individual golfers' handicaps were presented in [4]. The interest of these studies lies in the formation of foursomes to make the game of golf fair and interesting. A statistical analysis from the viewpoint of golf course management can be found in [5], where the tee time intervals between foursomes were investigated to maximize the revenue of a golf course. It was shown by simulation that there exists an optimum tee time interval to maximize the revenue–in other words, minimizing the waiting time of foursomes.

We have an interest similar to that of [5] and investigate the operation of foursomes with respect to the entire 18-hole playing time. Compared with [5], our approach has the following improvements in the analysis: first, we compare different types of dispatching formats, namely, regular and shotgun; second, our state transition diagram of a foursome in a hole is more realistically modeled by differentiating the tee box and fairway waits; third, a concurrent simulation is executed to model the behavior of foursomes.

When there is only one foursome on a golf course, the time to finish a round of golf can be modeled as an independent random variable. As the time for shooting golf balls and walks are nearly deterministic, the randomness in the playing time mainly comes from the time to search for the balls on the course. When multiple foursomes play on a golf course in sequence, there are two random factors to be considered for the playing time of an individual foursome: the time to search for the balls, which is not

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affected by other foursomes, and the waiting time due to the unavailability of the fairway. Basically, as a golf shot can be dangerous to the foursome ahead, golfers are allowed to shoot only if the foursome ahead has proceeded enough so that there is practically no chance that the shot becomes intimidating to the foursome ahead. Slow play by a foursome, therefore, can cause a long waiting time for the foursome behind, and it can have a ripple effect. Note that multiple foursomes' sequential play is common in most public golf courses. We use SystemC to model the concurrent behavior of foursomes, and each foursome is modeled as an object in the object-oriented paradigm.

II. System Model

We model the total time for a foursome to finish a round of golf as a sum of two random variables: the *playing* time, where its randomness is not affected by other foursomes, and the *waiting* time, which is solely decided by the status of the foursome ahead. In particular, we investigate how the different types of game formats affect the total time to play a round of golf. We consider the regular and shotgun formats. The *regular* format means that every foursome starts at hole 1, plays each hole in order, and finishes the game at the last hole. In the regular format, therefore, each foursome has a different starting time. The *shotgun* format means that all the foursomes start at the same time but at different holes and proceed in a circular fashion. For example, a foursome starts at hole 12, proceeds until the last hole, then returns to hole 1 to finish at hole 11. Note that, in the shotgun format, multiple foursomes (usually two) can start at the same hole, but one foursome starts after the other. An advantage of shotgun is that all the foursomes on the golf course begin at the same time and finish their rounds at roughly the same time. However, in shotgun, due to its circular formation, a ripple delay effect can be manifested, and the playing time can be much longer than that of the regular format.

Figure 1 shows how the behavior of a foursome is modeled by a finite state machine, and Fig. 2 shows how the holes are modeled from the shared resource's point of view. At a par-4 hole, for example, as soon as the foursome ahead finishes the fairway shot and starts walking, a foursome can start their own tee shots. The foursome proceeds until the *fairway shot wait* state and waits until the green is cleared. The foursome ahead finishes their putting and moves to the next tee box. Par-3 and par-5 holes are differently modeled by adjusting the number of mid-fairways. In Fig. 1, the waiting (playing) time corresponds to the sum of times sojourning at the (un)colored state. Each playing time is modeled as a uniform random variable in the simulation. We assume that the statistics of the random variable are decided according to players' handicaps.

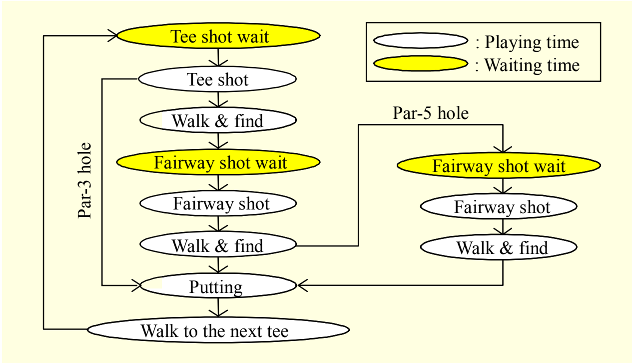

Fig. 1. State diagram of a foursome in golf.

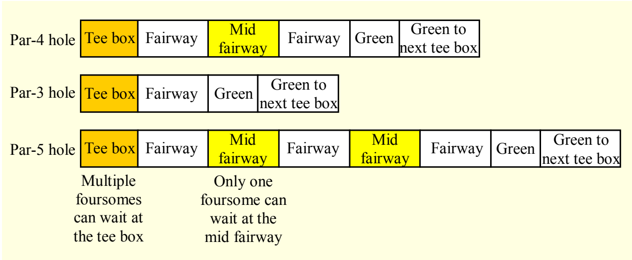

Fig. 2. Hole modeling.

III. Simulation with Concurrency and Analysis

We simulated the game of golf using the proposed approach. The course layout of the Torrey Pines' South course[1)] was used. We varied the number of foursomes on the course from 9 to 36 and measured the total (waiting plus playing) time as shown in Fig. 3. For the specific scenario we tested, the shotgun format took less time than the regular format for all foursomes to complete when the number of foursomes was less than 33. However, for more foursomes, the regular format took less time, confirming the belief that the shotgun format can take longer than the regular format. We conjecture that this is because the number of waiting and idling foursomes increases steeply as more foursomes play on the course, thus resulting in longer waiting time. From the perspective of golf course management, it may not be wise to take the shotgun format if 33 or more foursomes need to be accommodated.

Figure 4 compares the total time of foursomes with different handicaps. We define three levels of handicaps, A having the lowest minimum and maximum values for the ball-searching uniform random variable and C having the largest. The random variables for playing times are independently generated according to the uniform distribution. Considering all the randomness in the playing time, a level-A foursome finishes par-4 holes in 7 min to 12 min, whereas a level-C foursome

1) The course layout can be found at www.torreypinesgolfcourse.com.

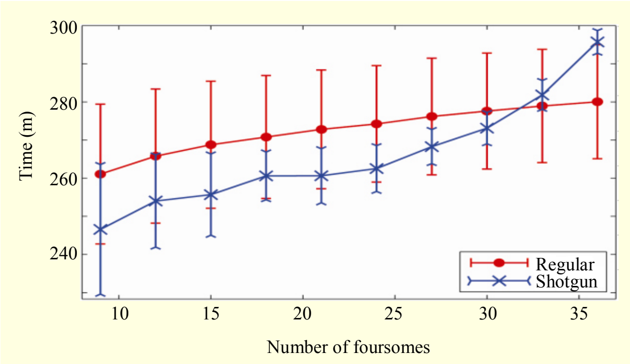

Fig. 3. Average total time.

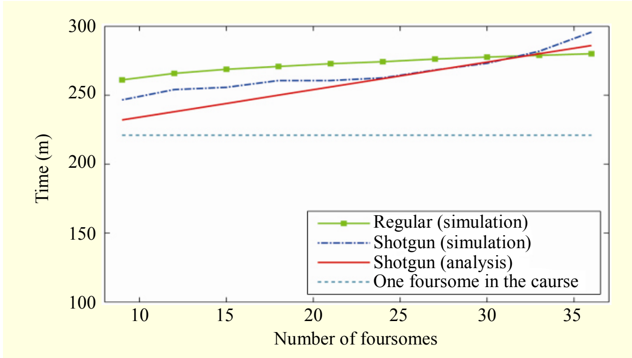

Fig. 5. Comparison with mean analysis.

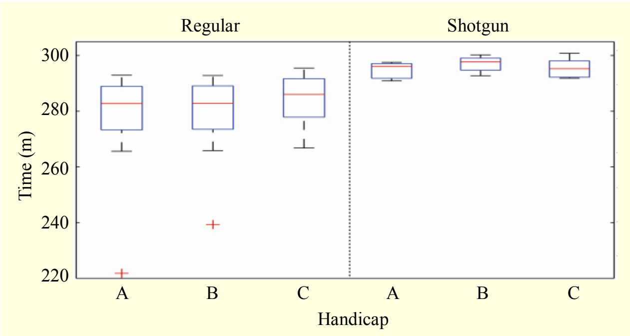

Fig. 4. Box-and-whisker plots of total time.

finishes in 12 min to 20 min. The results show that the total time was less sensitive to handicaps in the regular format. In the shotgun format, the foursomes with middle-level handicappers were penalized to the largest extent, thus, potentially decreasing the satisfactory level of average players.

If we model a hole as a queue, one round of an 18-hole golf course can be regarded as 18 tandem queues for the regular format and as 18 closed queues for the shotgun format. For the latter, given a closed queuing network with s customers, define $N_i(s)$ as the average number of customers (that is, foursomes) in the i-th queue, where i=1, 2,$\cdots$, 18. In an s-customer closed network, the average number of customers found upon arrival by a customer at the i-th queue is thus equal to $N_i(s-1)$, the average number seen by an observer in the $(s-1)$-customer closed network. Let us assume for simplicity that each queue has one server (that is, the green) of service rate μ and that the average time spent from the teeing ground to the green is d. The average customer time spent per visit in the i-th queue can be written as

$$T_i(s) = \frac{1}{\mu}\left[1 + N_i \cdot (s-1)\right] + d. \tag{1}$$

For 18 queues of holes, the entire time in a round becomes

$$T(s) = \sum_{i=1}^{18} T_i(s) = \frac{s+17}{\mu} + 18d, \tag{2}$$

which linearly increases with s. Using the values of μ and d obtained from the experiments presented in this section, we can draw Fig. 5. As there is no closed form expression for the delay in the tandem queue, we only compare the simulation results against the average playing time, which is obtained when only one foursome plays on the golf course. We can also observe that the shotgun format takes longer than the regular format when the number of foursomes exceeds 30.

IV. Conclusion

We have proposed a novel SystemC-based concurrent simulation method for modeling the game of golf. According to our simulation results and stochastic modeling, our approach is realistic and useful for quantitative analysis of golf. The proposed technique will be helpful for engineering design activities in which different configurations of resources should be determined for achieving optimal performance.

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