An Agent-based Collaborative Model for Orthopedic Outpatient Scheduling

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***Abstract*—In many Asian countries, healthcare system has a mixed-type registration which accepts both walk-in patients and scheduled patients. That makes outpatient scheduling a difficult task and results in long outpatient waiting time. Nowadays, hospitals in Taiwan emphasize on providing high quality service for patients. Survey of outpatient satisfaction showed that at Taoyuan Armed Forces General Hospital the long waiting time is by far the most dissatisfied service quality. Current data shows those outpatients need to wait for an average of up to two hours before being served. In attempt to reduce outpatient waiting time, we proposed a genuine agent-based adoptive scheduling model for service sectors within which fixed scheduling rules will not work because humans are autonomous and their behavior will change according to the real-time situation and the scheduling rules applied. The proposed model uses software agents to dynamically adjust the scheduling rules to adapt to the real-time situation in the clinic. Simulation models were built based on two months of data collected manually from the hospital to test the proposed model. Results showed that agent-based collaborative control system can reduce waiting time by29%~36% for walk-in patients and 61%~63%for scheduled patients respectively.**

Keywords—Agent-based collaborative model; Outpatient waiting time; Simulation

I. INTRODUCTION

The long waiting time of outpatient is caused by the unpredictable patient behavior as well as by the outpatient registration and scheduling system which accepts both walk-in patients and scheduled patients. The long waiting time happened not only in Taiwan (population 23,261,747), but also in many countries of Asia such as China (population 1,347,350,000), India (population 1,210,193,422) Japan (population 127,950,000), Thailand (population 67,041,000), etc. Those countries account for a total of 39.14% of the world population.

The competition among healthcare providers in Taiwan has become intense because there are a lot of clinics and hospitals. Also, people in Taiwan can select healthcare providers freely under National Health Insurance (NHI). In order to create competitive advantages, it is critical for healthcare providers to increase the service quality level [1].Many research indicated patient waiting time is a key performance index which affects patient satisfaction for medical industry [2, 3].Survey of outpatient satisfaction showed that the long waiting time is by far the most dissatisfied service factor of the Taoyuan Armed Forces General Hospital.

In this study, we worked collaboratively with Taoyuan Armed Forces General Hospital, which is one of the regional medical centers in Taiwan and provides a wide variety of services that includes 667 patient beds and more than about 20 departments that serve about 5,000,000 visits of patient per year. The orthopedics department at Taoyuan Armed Forces General Hospital has three teams, including hand and foot team, sport team, and trauma team. This research focuses on hand and foot team that has two doctors and 10,000 patient visits per year. The two doctors have three different consultation sessions which are quite different in terms of behavior of the doctor, the number of patients per day, the number of special patients, and the arrival time of walk-in patients before consultation, and total service time for an outpatient. This research focuses on improving clinic service by reducing outpatients waiting time in the Hand and Foot Team of the orthopedic surgery department. The clinic service processes are shown as Fig.1.

Conventional scheduling models have preset scheduling rules that are fixed. These conventional scheduling models are appropriate for applications such as factories where, for examples, machine hours required for a job and capacity of a machine will not be affected by scheduling rules. However, patients, doctors, and medical staffs are not like products and machines. Patients, doctors, and medical staffs are autonomous and their behavior in the clinic will be affected by different outpatient scheduling rules. Therefore, conventional scheduling models cannot be adapted to the clinic

978-1-4799-3776-9/14/$31.00 ©2014 IEEE

environment. This study proposed an agent-based adoptive scheduling model which uses software agents to dynamically adjust the scheduling rules to adapt to the real-time situation in the clinic. This study used the orthopedic department of Taoyuan Armed Forces General Hospital as a test bed. This study built three simulation models of the orthopedics clinic and applied agent-based collaborative control system in attempt to reduce outpatient waiting time and to improve hospital efficiency and patient satisfaction.

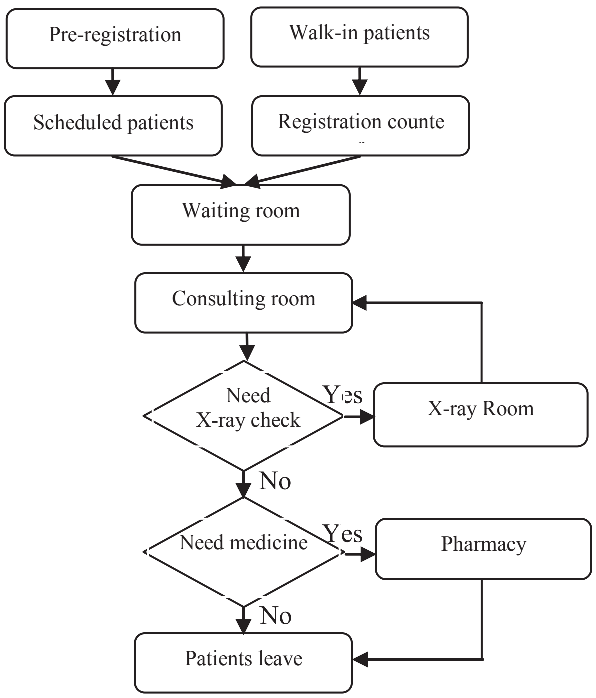

Fig.1 Orthopedics clinic process

II. LITERATURE REVIEW

A. Agent-based Model

Agent-based model is a class of computational models for simulating the action sand interactions of autonomous agents with a view to assessing their effects on the system. J. Nealon and A. Moreno[4]suggested that an agent is a software entity that applies Artificial Intelligence techniques to choose the best set of actions to perform in order to reach a goal specified by the user. The agents can react timely and flexibly to the dynamic and unexpected changes in their environment and can communicate with users or other agents. Thus, they can exchange information, engage in complex negotiations, and coordinate their activities to cooperate in the joint resolution of a problem. Aburukba et al.[5] suggested that in agent-based systems, scheduling usually involves complex and on-deterministic interactions between different participating tasks and resources. C. W. Reynolds[6] revolutionized computer simulation of agents. He introduced individual perception, intelligence and behavior to his Boids agents, and therefore allowing emergent pattern based on a large group of constituent units to be simulated. Decker and Jinjiang[7] proposed a system to increase hospital efficiency using global planning and scheduling techniques. The nature of healthcare system generally involves the coordination of the effort of several individuals (e.g., physicians, nurses, social workers) with different skills and needs that located in different places. Usually there is no attention of having a centralized coordinator, so the computerized systems can be difficult. Under these conditions, the agent-based model is a good option to be used in healthcare applications. Lanzola et al. [8]presented a methodology that facilitates the development of interoperable intelligent software agents for medical applications and propose a generic computational model for implementing them. N. R. Jennings[9] suggested that agent-based computing should not be viewed merely as a good solution technology. Rather, it should be seen in its broader context as a general-purpose model of computation that naturally encompasses the major trends in software. In particular, there is an inexorable move towards distributed and concurrent systems as the norm.

B. Outpatient Waiting Time

Long waiting time usually happens in many service organizations and especially in outpatient departments[10]. Furthermore, countries have been demonstrating that waiting time at outpatient clinics is the major problem [11]. Wijewickrama[10] indicated the main reason why patients in many outpatient departments complain is because the long waiting time for treatment followed by short consultations

Reducing long waiting time is a direct way to improve patient satisfaction and service quality. There are past researches attempting to improve long waiting time, shown in Table I. These proposed approaches were able to reduce patients waiting time, but did not consider the changing human behaviors according to scheduling rules and hence were not able to adjust scheduling dynamically according to real time clinic situation.

TABLE I. REDUCING WAITING TIME APPROACHES

Research	**Approaches**	**Results**
Syi Su, Chung-Liang Shih[12]	Using established simulation models, the effects of various scheduling policies on patients' throughput time and waiting times were revealed.	Resulting waiting times (average: 8.0 minutes vs 12.5, 12.3, and 20.5 minutes) for scheduled patients compared with other registration strategies. Resulting waiting times (average: 14.7 minutes vs 34.9, 35.8, and 25.8 minutes) for walk-in patients compared with other registration strategies.

AthulaWijewickrama, SoemonTakakuwa[13]	A special purpose data generator was designed to validate the model and to conduct experiments in bottleneck situations at consultation rooms in the existing system.	As a result of this, the total number of patients waiting for consultation for a day was reduced from a hundred and fifteen to fifty five, a 52 percent reduction compared to the existing system.
Thomas R. Rohleder, Peter Lewkonia, Diane P. Bischak, Paul Duffy, Rosa Hendijani[14]	Building model to help identify improvement alternatives including optimized staffing levels, better patients scheduling, and an emphasis on staff arriving promptly.	The model predicted that nearly 80% of patients would finish their visits in 60 minutes or less. The actual result after implementing the improvements was a substantial reduction in time in the clinic of about 22minutes per patient on average.
Chen-Fu Chien , Fang-Pin Tseng, Chien-Hung Chen[15]	Develop an evolutionary approach based on genetic algorithm for solving the problem.	All patients registered in advance are scheduled by the proposed GA have an average waiting time of 10 minutes or less. 50% of the patients registered in advance are scheduled by the hospital’s empirical method. The other 50% are in-patients following the exponential distribution that the average waiting time is 20 minutes or less.
L. J. Groome and E. J. J. Mayeaux[16]	Illustrated factors that will affect waiting time such as arrival time, failure to attend, consultation time and registration time, etc.	A significant decrease in mean waiting time (32.7 +/- 23.6 minutes vs 29.3 +/- 21.2 minutes, t = 3.42, P < .001); and a significant improvement in the waiting time distribution (Kruskal-Wallis test of homogeneity, P = .003).
Guangfu Tai, Peter Williams[17]	Probability plots method is proposed for optimal patient interval setting to minimize waiting time of both patient and the doctor.	The appointment intervals are 11, 12, 13, 14 and 15 minutes. And the simulation results of total average waiting time are shown respectively as following: 13.66, 13.72, 14.13, 13.36 and 13.03 minutes, which are the sum of average waiting and idle time for patient and doctor.

III. RESEARCH METHODOLOGY

A. Simulation Models

The purpose of this research is to improve patient waiting time and promote clinical service quality by using an agent-based collaborative control system.

There are two types of patients in the orthopedics clinic. Walk-in patients need to come to the hospital to register and wait for consultation in the waiting room. The number of walk-in patient is limited to 30, which causes many walk-in patients to come early and register before consultation session is opened for service. Other walk-in patient may arrive at any time during the consultation session with numbers varies greatly from session to session. That means walk-in patients may introduce great uncertainty to outpatient scheduling. Scheduled patients can register using either an automatic registration machine, examination room reservation, voice system telephone or through an Internet reservation system one day before the clinic session. Some of the clinic patients have a high tendency to be late, to be a no-show patient or to cancel the registration at last minute. All the above patient behaviors make scheduling for outpatient a complicate and difficult task.

This research used log data from administration system of the hospital together with data we collected manually in the field. The data includes patients’ registration number, registration time, registration type, service start time, service stop time, average number of patients in one day, no-show rate, late rate, service time, X-ray test time, waiting time (WT), and the throughput time (TPT) for the two types of patients. Arena version 13.9 was used to build the simulation model. Walk-in patients’ arrival time, patients’ service time, and test time arrival time data were fitted into distributions by Arena.

Kolmogorov-Smirnov test will be used for the goodness-of-fittest of the distribution. The Kolmogorov-Smirnov test is under null hypothesis that the sample comes from the hypothesized distribution F(x),in distribution,

$$\sqrt{n}D_n \xrightarrow{n\to\infty} \sup_t |B(F(t))| \tag{1}$$

where B(x) is the Brownian Bridge[18]. If F is continuous then under the null hypothesis $\sqrt{n}D_n$ converges to the Kolmogorov distribution, which does not depend on F. The goodness-of-fittest or the Kolmogorov-Smirnov test is constructed by using the critical values of the Kolmogorov distribution. The null hypothesis is rejected at level α under Eq. (2)

$$\sqrt{n}D_n > K\alpha, \tag{2}$$

$$pr(K \le K\alpha) = 1-\alpha \tag{3}$$

where Kα is found from Eq. (3).

There are two doctors who have three different consultation sessions in the Hand and Foot Team Clinic of orthopaedic surgery department. These sessions have different characteristics such as behavior of the doctor, the number of patients per day, the number of special patients, walk-in patients’ arrival time before consultations and total service time for an outpatient. Therefore, this research builds three different simulation models for the following three consultation sessions respectively.I: Dr. A's morning consultation session, II: Dr. A's afternoon consultation session, and III: Dr. B's morning consultation session. One of the simulation models are shown on the Fig. 2.

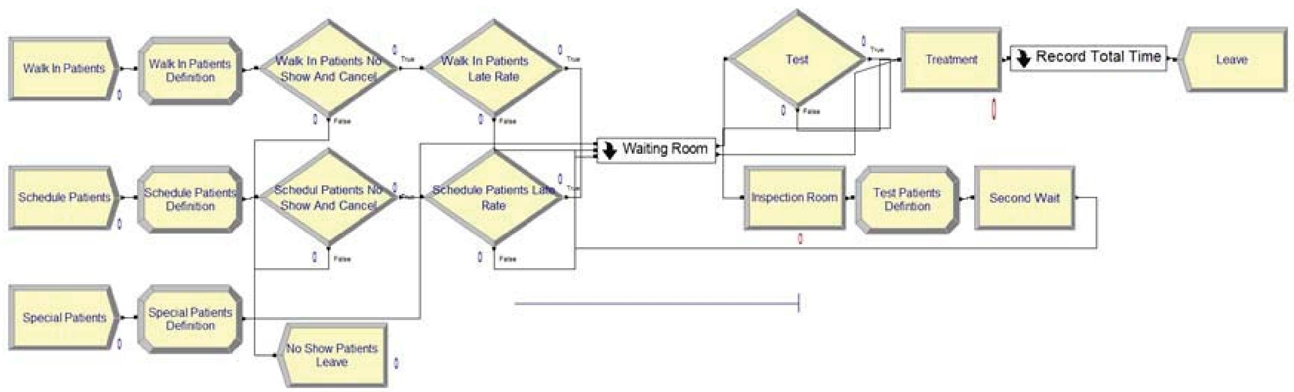

Fig.2. Simulation models

B. The Agent-based Collaborative Control System

The agent-based control system model is shown in Fig.3. It consists of nine agents. The walk-in patients agent,scheduled patients agent, doctor agent, and nurses agent will keep monitoring the current number and status of the walk-in patient, scheduled patient, doctors, and nurses and provide these information to x- ray check agent, waiting room agent, late patients agent, and clinic service agent. The X-ray check agent will provide the number of both types of patients waiting for X-ray check and X-ray status to the scheduling agent. The waiting room agent will provide the number of both types of patients in the waiting room outside of the doctor's consultation room to the scheduling agent. The late patient agent will provide the number of both types of patients who are late to the scheduling agent.The clinic service agent will provide the current status of doctor and nurses to the scheduling agent. With the information received from other agents in the model, the scheduling agent will be able to make scheduling decisions in real-time.

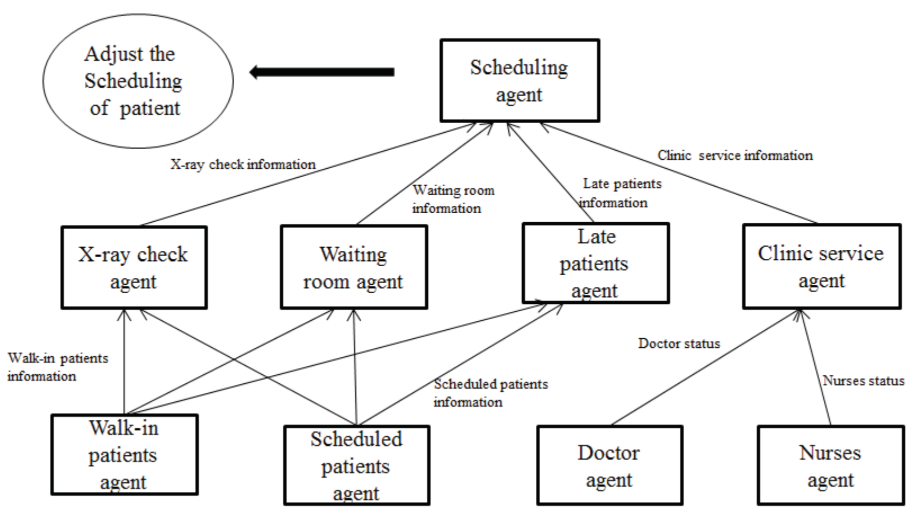

Fig. 3. The agent-based control framework.

The current decision rules for the scheduling agent are:

- If walk-in patients are three more or above than scheduled patients in the control model waiting for consultation, the sequences will be three walk-in patients followed by one scheduled patient.

- If scheduled patient are three more or above than walk-in patients in the control modelwaiting for consultation, the sequences will be three scheduled patients followed by one walk-in patient.

- Under all other situations, the sequence will be one scheduled patient followed by one walk-in patient.

The scheduled patients are scheduled to arrive one hour later than the walk-in patients

IV. SIMULATION RESULTS

The simulation results were shown in Table II. The agent-based collaborative control system results in significant reduction in waiting time for both scheduled and walk-in patients. For session I Dr. A's morning session, the average improvement of walk-in patient waiting time is 33%, from 110.3 minutes to 74.2 minutes and the average improvement of scheduled patient waiting time is 63%, from 56.2 minutes to 20.6 minutes. For session II Dr. A's afternoon session, the average improvement of walk-in patient waiting time is 29%, from 130.2 minutes to 93 minutes and the average improvement of scheduled patient waiting time is 63%, from 61.9 minutes to 23.2 minutes. For session III Dr. B's morning session, the average improvement of walk-in patient waiting time is 36%, from 71.3 minutes to 45.9 minutes and the average improvement of scheduled patient waiting time is 61%, from 39.4 minutes to 15.2 minutes.

The significant reduction in waiting time is a result of applying the agent-based adoptive scheduling model which uses software agents to dynamically adjust the scheduling rules to adapt to the real-time situation in the clinic. For example, walk-in patients usually come inearlybecausethe number of walk-in patient for each consultation session is limited. The agent-based adoptive scheduling model was able to schedule more walk-in patient to be served at the early stage of the session and hence reduce the average waiting time. .

TABLE II. WITH AGENT-BASED COMPARE

Model	Patient type	Before(minutes)	After(minutes)	Improvement
Session I Dr. A's morning	Walk-in waiting time	110.3	74.2	33%
	Scheduledwaiting time	56.2	20.6	63%
Session II Dr. A's afternoon	Walk-in waiting time	130.2	93	29%
	Scheduled waiting time	61.9	23.2	63%
SessionIII Dr. B's morning	Walk-in waiting time	71.3	45.9	36%
	Scheduled waiting time	39.4	15.2	61%

V. CONCLUSIONS

According to the annual survey done by the Taoyuan Armed Forces General Hospital, the service quality that needs to be improved first is the long outpatient waiting time. This study proposed a genuine agent-based adoptive scheduling model for service sectors within which fixed scheduling rules will not work because humans are autonomous and their behavior will change according to the real-time situation and the scheduling rules applied. The proposed model uses software agents to dynamically adjust the scheduling rules to adapt to the real-time situation in the clinic. This research focuses on the Hand and Foot Team Clinic of the orthopedic surgery department. Three simulation models were built for 3 different consultation sessions. The simulation results showed that the proposed agent-based collaborative control system can significantly reduce outpatient waiting time for both scheduled patients and walk-in patients.The improvements range from29% to 36%for walk-in patients and 61% to 63% for scheduled patients.Themodel can be a research foundation for related study in the field of agent-based models and adaptive scheduling for service sectors.Further research may apply the proposed model to other departments in the hospital.

ACKNOWLEDGMENT

This project is partially sponsored by the Research FoundationofTaoyuan Armed Forces General Hospital.

REFERENCES

[1] J. Reynolds*, et al.*, "Design and analysis of a health care clinic for homeless people using simulations," *International Journal of Health Care Quality Assurance,* vol. 23, pp. 607-620, 2010.

[2] G. M. Eilers, "Improving patient satisfaction with waiting time," *Journal of American College Health,* vol. 53, pp. 41-48, 2004.

[3] T. R. Rohleder*, et al.*, "Using simulation modeling to improve patient flow at an outpatient orthopedic clinic," *Health Care Management Science,* vol. 14, pp. 135-145, 2011.

[4] J. Nealon and A. Moreno, "Agent-based applications in health care," in *Applications of software agent*

technology in the health care domain, ed: Springer, 2003, pp. 3-18.

[5] R. Aburukba, *et al.*, "Agent-Based Approach for Dynamic Scheduling in Content-Based Networks," in *e-Business Engineering, 2006. ICEBE '06. IEEE International Conference on*, 2006, pp. 425-432.

[6] C. W. Reynolds, "Flocks, herds and schools: A distributed behavioral model," *SIGGRAPH Comput. Graph.,* vol. 21, pp. 25-34, 1987.

[7] K. Decker and L. Jinjiang, "Coordinated hospital patient scheduling," in *Multi Agent Systems, 1998. Proceedings. International Conference on*, 1998, pp. 104-111.

[8] G. Lanzola, *et al.*, "A framework for building cooperative software agents in medical applications," *Artificial Intelligence in Medicine,* vol. 16, pp. 223-249, 1999.

[9] N. R. Jennings, "On agent-based software engineering," *Artificial intelligence,* vol. 117, pp. 277-296, 2000.

[10] A. K. A. Wijewickrama, "Simulation analysis for reducing queues in mixed-patients' outpatient department," *International journal of simulation modelling,* vol. 5, pp. 52-68, 2006.

[11] G. C. Kaandorp and G. Koole, "Optimal outpatient appointment scheduling," *Health Care Manage Sci,* vol. 10, pp. 217-229, 2007.

[12] S. Su and C.-L. Shih, "Managing a mixed-registration-type appointment system in outpatient clinics," *International Journal of Medical Informatics,* vol. 70, pp. 31-40, 2003.

[13] A. Wijewickrama and S. Takakuwa, "Simulation analysis of appointment scheduling in an outpatient department of internal medicine," presented at the Proceedings of the 37th conference on Winter simulation, Orlando, Florida, 2005.

[14] T. Rohleder, *et al.*, "Using simulation modeling to improve patient flow at an outpatient orthopedic clinic," *Health Care Management Science,* vol. 14, pp. 135-145, 2011.

[15] C.-F. Chien, *et al.*, "An evolutionary approach to rehabilitation patient scheduling: A case study," *European Journal of Operational Research,* vol. 189, pp. 1234-1253, 2008.

[16] L. J. Groome and E. J. J. Mayeaux, "Decreasing Extremes in Patient Waiting Time," *Quality Management in Healthcare,* vol. 19, pp. 117-128 10.1097/QMH.0b013e3181dafeac, 2010.

[17] G. Tai and P. Williams, "Optimization of scheduling patient appointments in clinics using a novel modelling technique of patient arrival," *Computer Methods and Programs in Biomedicine*.

[18] Wikipedia. (2012/1/28). *Kolmogorov-Smirnov_test*. Available: http://en.wikipedia.org/wiki/Kolmogorov-Smirnov_test