Chapter 7

Discrete-Event Simulation Research Team

7.1 Members

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7.2 Research Activities

Discrete-event simulations cover much wider fields than discretized simulations of continuous models. They comprise various kinds of models, for example, particles, agents, automata, games and so on, and their applications are from material and biomedical sciences to ecological and environmental problems. Social designs and controls have becoming the more interesting target since so-called the "big data sciences" became popular. In addition, continuous simulations are also becoming building block of discrete-event simulations. The discrete-event simulation research team (DESRT) aims to cultivate such applications of supercomputers. There are mainly two directions of activities. One is to develop application softwares. We have been developing job management applications OACIS and CARAVAN. The other is to study and develop models for complex phenomena, mainly in social ones.

7.2.1 Job management applications, OACIS and CARAVAN

A characteristic feature of discrete-event models is their large and complex parameter spaces, and they often show qualitatively different various behaviors with different parameters. Supercomputers help to overcome such difficulty: their performance with extreme parallelism allows us to simulate huge number of parameter sets.

There are two kinds of computer jobs: one pursues computing capability and the other capacity. Discrete-event simulations are in the capacity computing, and many simulations are necessary to be prepared and executed efficiently. Table 1.1 shows a classification of computer jobs in terms of their capacity. But manual operation and orchestration of thousands and more jobs are hard, and application tools for the purpose are usually used. The OACIS and CARAVAN are applications developed and released in our team. OACIS since 2012 can manage most jobs interactively through web browser up to millions. CARAVAN since 2017 handles more jobs assuming that input and output size of each job be small. In this year 2018, major updated for the OACIS[33] and minor one for the CARAVAN[34] were done, together with user-support activities and tutorials. Now the applications of them are growing, for example a Robocup system[9].
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<table>
<thead>
<tr>
<th>class</th>
<th>capability computing</th>
<th>capacity computing</th>
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<tbody>
<tr>
<td>A</td>
<td>manual execution</td>
<td>easy</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>tedious</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>troublesome</td>
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<td>D</td>
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<td>desperate</td>
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| number of simulations | \( \sim 10^1 \) | \( \sim 10^4 \) | \( \sim 10^7 \) | \( \sim 10^{10} \) and more |
| (node · second) per simulation | \( \sim 10^{10} \) and more | \( \sim 10^7 \) | \( \sim 10^8 \) | \( \sim 10^9 \) |
| output per simulation | \( \sim \) TB and more | \( \sim \) GB | \( \sim \) MB | \( \sim \) KB |

Table 7.1: A classification of jobs in terms of necessary number of simulations. The OACIS is designed for jobs for class A, B and C, and the CARAVAN for C and D.

Figure 7.1: Schematic picture of the implementation of exhaustive traffic simulation using the CARAVAN on the K computer is shown.

#### 7.2.2 Social modeling and simulations

##### 7.2.2.1 Traffic model: power-law distribution

The DESRT has been developing a car-traffic simulator of the Kobe city. It is used to see how computer simulations contribute to analyze, predict and optimize modern traffic issues like efficiency, congestion and pollution. After reproducing and analyzing current Kobe traffic in the previous year, simulations of artificial traffic is now challenged. For one traffic situation of the Kobe city, thousands of parameter samples were needed to be simulated to achieve statistically significant analysis. So we developed a simulator executing various artificial situations simultaneously using K computer[3]. It is prepared by combining the CARAVAN and the simulator for each parameter. The implementation and execution are shown in Fig. 7.1. Typically it took thirteen elapse hours for simulations of thousand parameter samples(see also Fig. 7.2).

Using this simulator, various simulations are systematically studied. One discovery is about distribution of traffic on road segments in urban traffic[4]. Simulation results from our Kobe simulator universally show a power-law distribution with decay exponent about 1. Similar power-law distribution was confirmed also on randomly generated road networks, but not on regular network with lattice structure. The latter shows a flat distribution(Fig. 7.3). This finding of universality classes in urban traffic flow may suggest that a randomly developed city and a regularly designed city have different traffic characteristics.
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Figure 7.2: A plot of process-load distribution for a set of execution of traffic simulations is shown.

Figure 7.3: Traffic distribution results from the Kobe city network(left), random(middle) and regular lattice(right) are shown. The horizontal axes marked with $N_v$ show total number of car passes through a road segment, that is, traffic of the segment. The vertical axes marked with $N_R/\Delta N_V$ show distribution density of number of road segments having $N_V$ traffic.
7.2.2.2 Collaboration strategy: a game theoretic approach

Global collaboration is no doubt the best way to overcome numerous serious obstacles and to settle our social and personal disputes. So it is a big challenge how to make collaboration without critical free-riders. One approach to this challenge is to use game theoretic models, and design games so that collaborative situations will be Nash equilibrium. Such equilibrium was formulated with a prisoner’s dilemma game in case of two players. It had not not been known for more players, but Yohsuke Murase, a member of DESRT, discovered ones for three players playing the tragedy of commons game with three-term memory and the results are published in this year 2018[6]. After prescreening of promising strategies among \(5 \times 10^{36}\) candidates were examined using the K computer. And 256 strategies were identified to make collaborating state the Nash equilibrium. One of them is listed in Tab. 7.2 and it is shown in Fig. 7.4. It looks complicated. We do not have any simple understanding and insight of these results. but this discovery will be a big leap towards global collaboration.

7.2.3 Other activities

In the year of 2017, following studies were published from this team:

Figure 7.4: Transition paths towards collaboration are shown.
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7.3 Schedule and Future Plan

From the research activities of DESRT so far, following problems are becoming clear:

[1] Simulation models, typically social ones, comprise with large input parameters and output numbers, and their behaviors are strongly nonlinear with various regimes.

[2] Social “big data” are often not big enough to picture details. It is clearly observed from our multivariate analysis of the traffic data. Thousands of samples are necessary to get minor traffic factors, but such repetitions are not expected in the real traffic. Weather, economics, calendar, accidents and other factors varies every day.


7.4 Publications

7.4.1 Articles


7.4.2 Invited Talks


7.4.3 Oral Talks
[22] Nobuyasu Ito, ”Social simulation and supercomputer” Department of Transportation System Planning and Telematics, Technische Universitaet Berlin, 2018 November 27th.
[28] 村瀬洋介 「繰り返し公共財ゲームにおける負けないことが保証された直接互恵戦略」、日本物理学会秋季大会（同志社大学、京田辺、京都、2018年9月9日—12日）
[32] 吉岡直樹、Ferenc Kun、伊藤伸泰、「熱活性破壊における微小亀裂発生点の統計分布」、日本物理学会秋季大会（同志社大学、京田辺、京都、2018年9月9日—12日）

7.4.4 Software
[33] OACIS v3.0.0-3.2.1 リリース https://github.com/crest-cassia/oacis
[34] CARAVAN(beta) v0.0.1-0.0.2 リリース https://github.com/crest-cassia/caravan