CENG4513
MODELLING & SILMULATION

LECTURE #1

Introduction

- *Simulation modeling* is a common paradigm for analyzing ***complex systems***.
- This paradigm creates a ***simplified representation*** of a system under study.
- The paradigm then proceeds to experiment with the system, guided by a prescribed set of goals, such as improved system design, cost–benefit analysis, sensitivity to design parameters, and so on.
- Experimentation consists of generating system histories and observing system behavior over time, as well as its statistics

1. Modeling

- Modeling is the creation of a *simplified representation* of a complex system with the goal of providing predictions of the system's performance measures (metrics) of interest. Such a simplified representation is called a ***model***.
- A model is designed to capture certain behavioral aspects of the modeled system—those that are of interest to the analyst/modeler—in order to gain knowledge and insight into the system's behavior (Morris 1967).

1. Modeling

- Modeling calls for *abstraction and simplification*.
- Therefore, if every facet of the system under study were to be reproduced in minute detail, then the model cost may approach that of the modeled system, thereby resulting against the reasons creating a model in the first place.
- Models are typically built precisely to avoid this unwanted/undesirable option.

1. Modeling

While modeling is ultimately motivated by economic considerations, several motivational strands may be discerned:

- Evaluating system performance under ordinary and unusual scenarios.
- Predicting the performance of experimental system designs.
- Ranking multiple designs and analyzing their tradeoffs.

2. Simulation Modelling

- The models that you will build and exercise are called *simulation models.*
- A simulation is often the next best thing to observing the real system.

i.e. The military performs war game exercises which are simulations of battlefield conditions.

i.e. An air- plane flight simulator can have emergency conditions for which it would be too dangerous or costly to provide in a physical-based simulation training scenario

2. Simulation Modelling

- Real-world systems are often too complex for analytical models and often too expensive to experiment with directly.
- Simulation models allow the modeling of this complexity and enable low cost experimentation to make inferences about how the actual system might behave.
- A key advantage of simulation modeling is that it has the capability of modeling the entire system and its complex interrelationships.

2. Simulation Modelling

- Most real-world systems are too complex to allow realistic models to be evaluated analytically, and these models must be studied by means of simulation. In a *simulation* we use a computer to evaluate a model *numerically*, and data are gathered in order to *estimate* the desired true characteristics of the model.

2. Simulation Modelling

Application areas for simulation :

- Designing and analyzing manufacturing systems
- Evaluating military weapons systems or their logistics requirements
- Determining hardware requirements or protocols for communications networks
- Determining hardware and software requirements for a computer system
- Designing and operating transportation systems such as airports, freeways, ports,
- and subways
- Evaluating designs for service organizations such as call centers, fast-food restaurants, hospitals, and post offices
- Reengineering of business processes
- Analyzing supply chains
- Determining ordering policies for an inventory system

3. Model Building

There are 8 major steps in model building:

1. Problem analysis and information collection:

- The first step in building a simulation model is to analyze the problem itself.
- In order to facilitate a solution, the analyst first gathers structural information that bears on the problem and represents it conveniently. This activity includes the identification of input parameters, performance measures of interest, relationships among parameters and variables, rules governing the operation of system components, and so on.

3. Model Building

2. Data collection:

- Data collection is needed for estimating model input parameters.
- The analyst can formulate assumptions on the distributions of random variables in the model.
- When data are lacking, it may still be possible to designate parameter ranges, and simulate the model for all or some input parameters in those ranges.

3. Model Building

3. Model construction:

- Once the problem is fully studied and the requisite data collected, the analyst can proceed to construct a model and implement it as a computer program.
- The computer language employed may be a general-purpose language (e.g., C++, Visual Basic, FORTRAN) or a special-purpose simulation language or environment (e.g., Arena).

3. Model Building

4. Model verification:

- The purpose of model verification is to make sure that the model is correctly constructed.

3. Model Building

5. Model validation:

- Every model is subject to validation.
- Model validation examines the fit of the model to empirical data (measurements of the real-life system to be modeled).
- A good model fit means here that a set of important performance measures, predicted by the model, match or agree reasonably with their observed counterparts in the real-life system.
- In practice, it is common to go through multiple cycles of model construction, verification, validation, and modification.

3. Model Building

6. Designing and conducting simulation experiments:

- Once the analyst judges a model to be valid, he or she may proceed to design a set of simulation experiments (runs) to estimate model performance and aid in solving the project's problem.

3. Model Building

7. Output analysis:

- The estimated performance measures are subjected to a thorough logical and statistical analysis.
- A typical problem is one of identifying the best design among a number of competing alternatives

3. Model Building

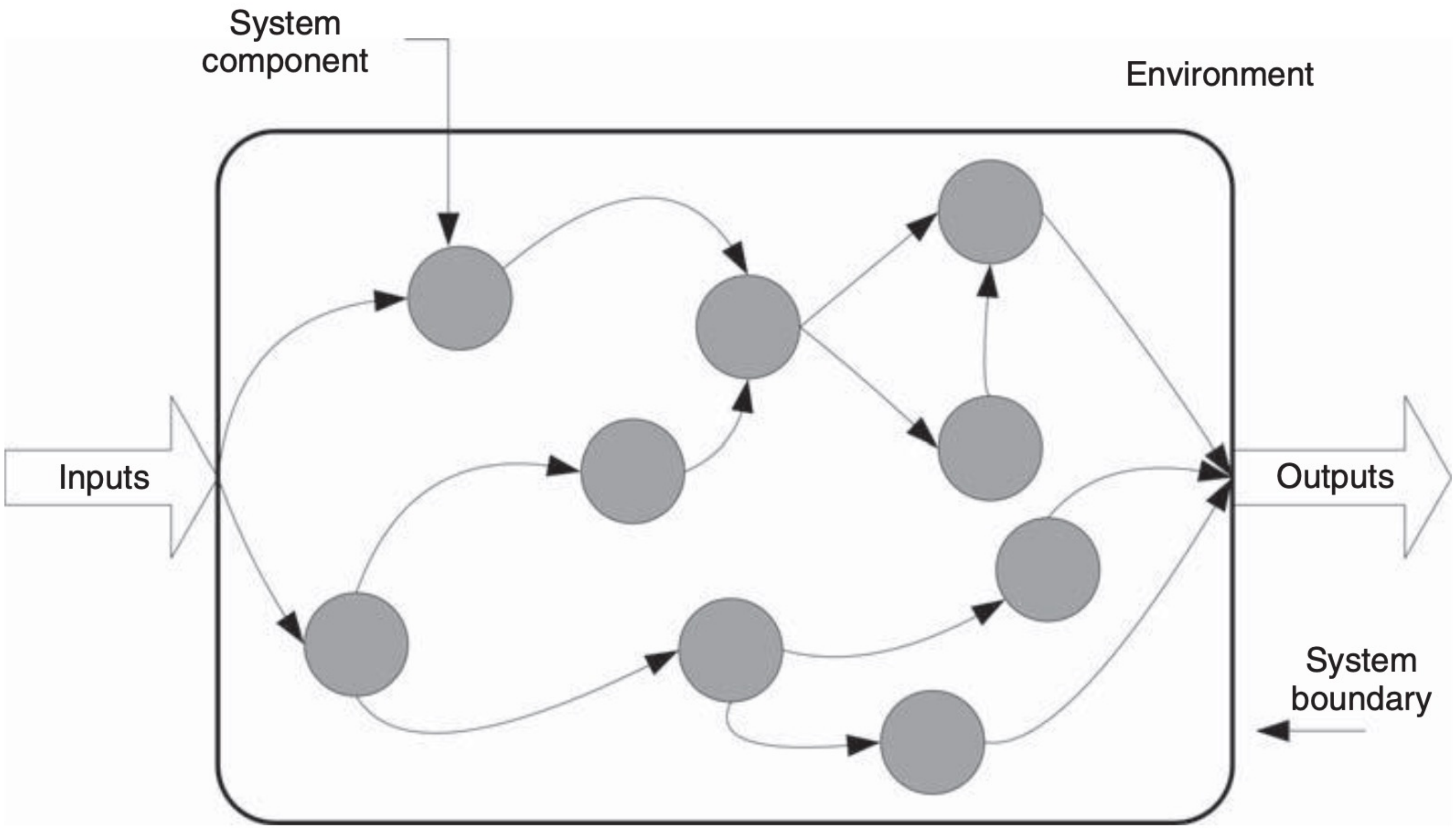
8. Final recommendations:

- Finally, the analyst uses the output analysis to formulate the final recommendations for the underlying systems problem.
- This is usually part of a written report.

4. Systems, Models & Simulation

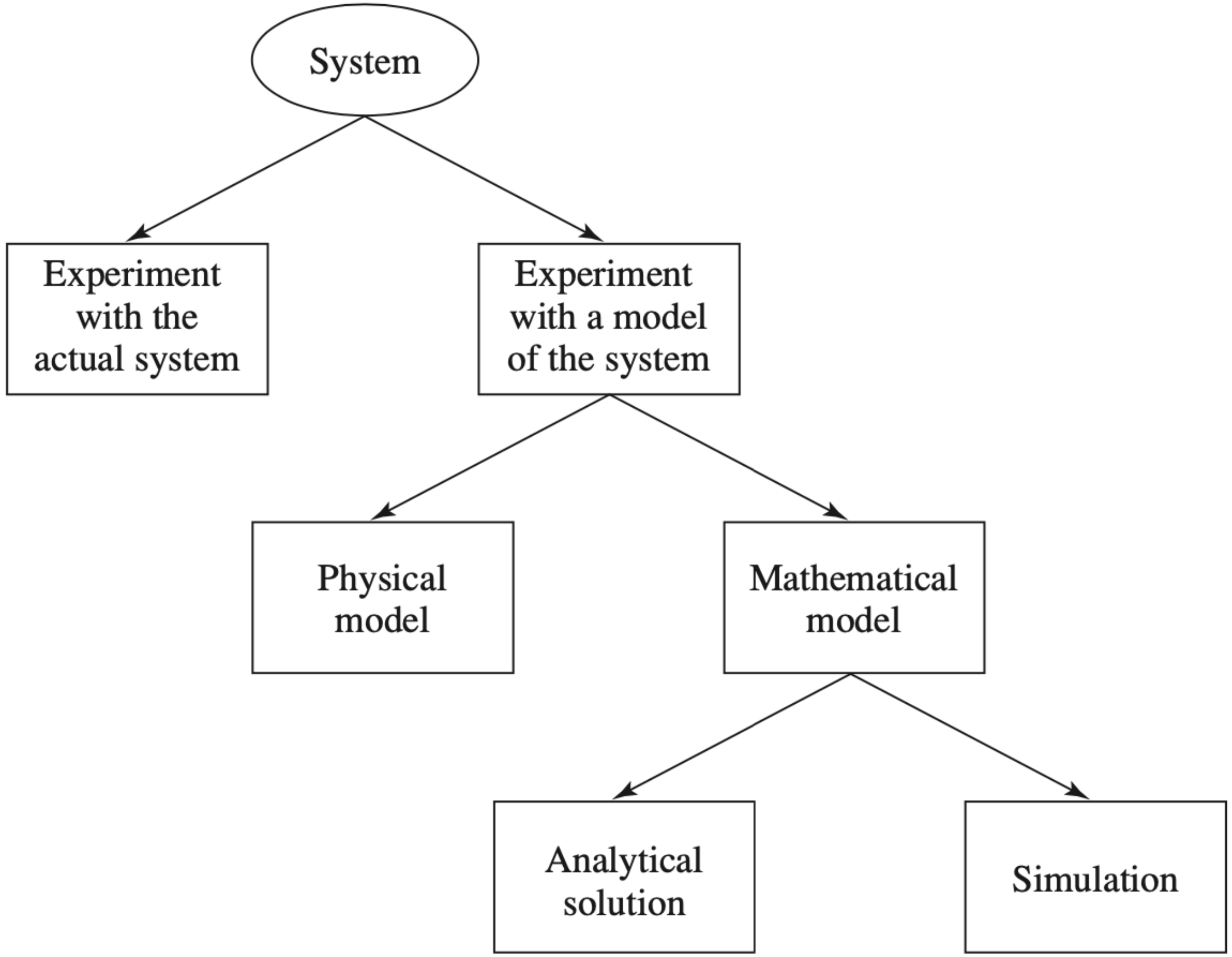
- A *system* is defined to be a collection of entities, e.g., people or machines, that act and interact together toward the accomplishment of some logical end. [Schmidt and Taylor (1970).]
- We define the *state* of a system to be that collection of variables necessary to describe a system at a particular time, relative to the objectives of a study

4. Systems, Models & Simulation



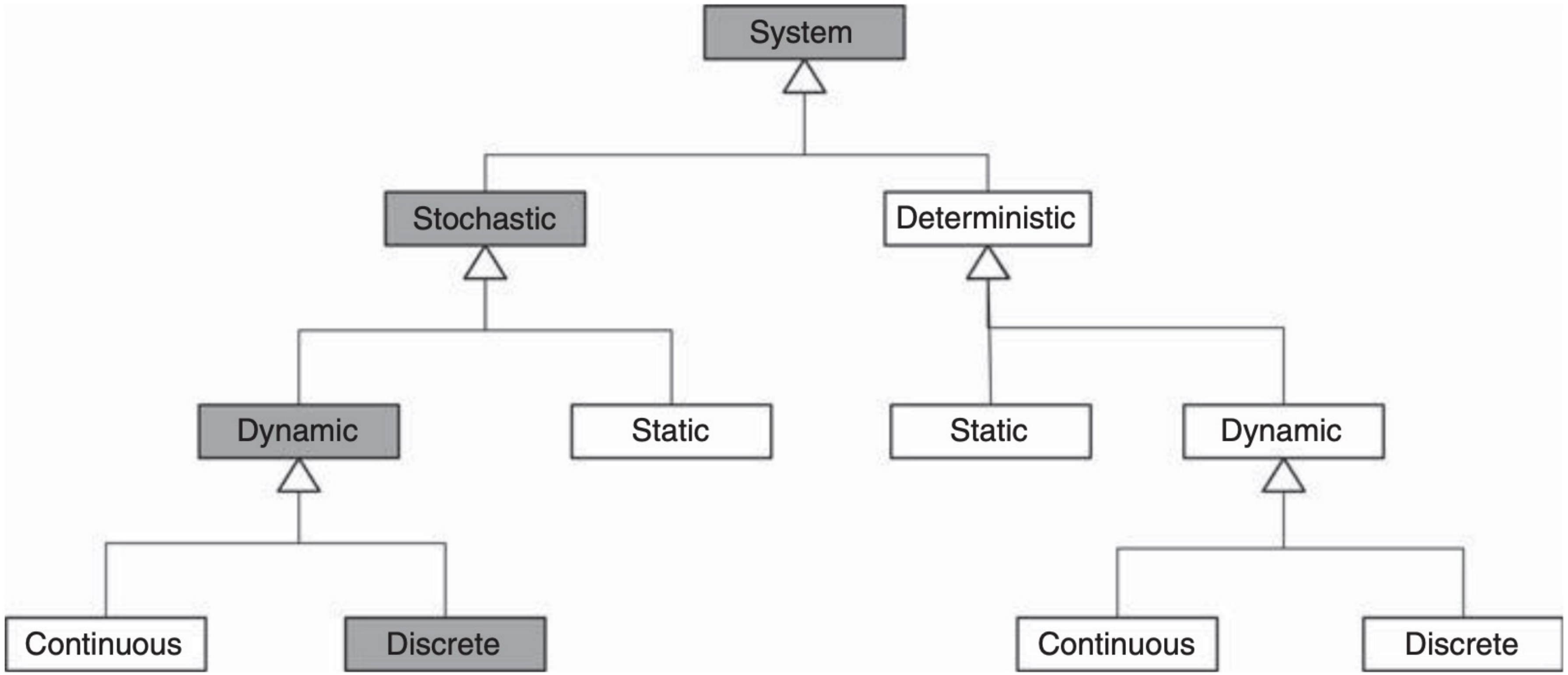
A conceptualization of a system

4. Systems, Models & Simulation



Ways to study a system

4. Systems, Models & Simulation



General types of systems

4. Systems, Models & Simulation

- The main purpose of a simulation model is to allow observations about a particular system to be gathered as a function of time.
- From that standpoint, there are two distinct types of simulation models:

  (i) discrete event and

  (ii) continuous

4. Systems, Models & Simulation

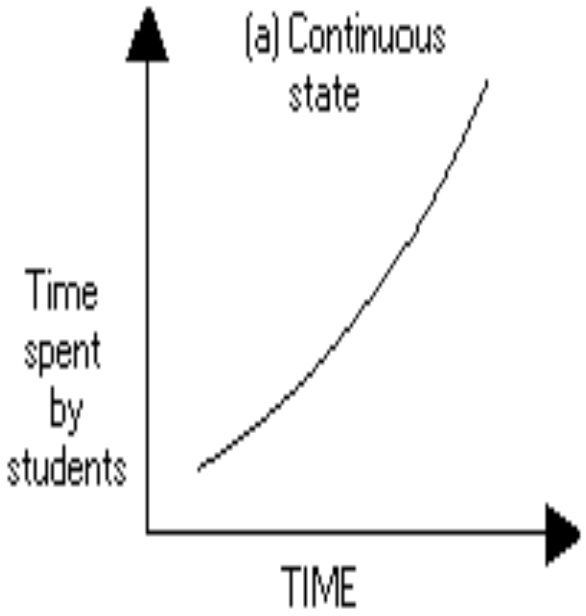
Discrete-event vs Continuous:

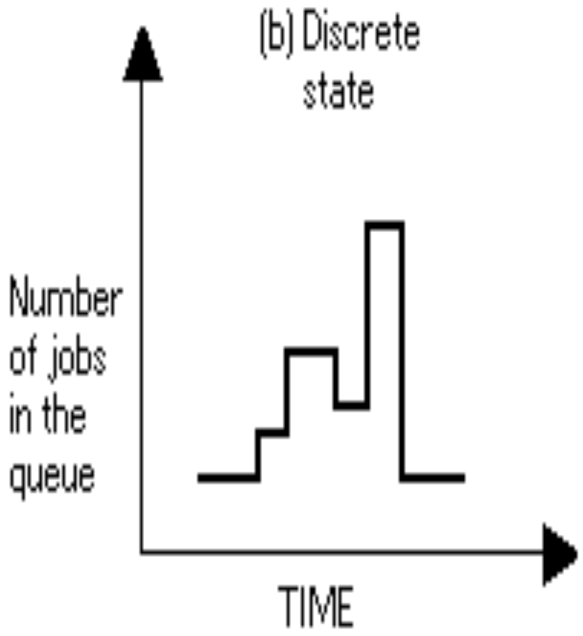
- Discrete systems change at *discrete points* in time. In a discrete-event simulation, observations are gathered at selected points in time when certain changes take place in the system. These selected points in time are called ***events***.

- On the other hand, continuous simulation requires that *observations be collected continuously at every point in time*

4. Systems, Models & Simulation

Discrete-event vs Continuous:





4. Systems, Models & Simulation

Discrete-event vs Continuous:

- **Example:** In the fast-food service counter system, changes in the status of the system occur either when a *customer arrives* to place an order or when the *customer receives their food*. The system does not need to be observed on a continuous basis. The system need ***only*** be observed at ***selected discrete points in time***, resulting in the applicability of a discrete-event simulation model

4. Systems, Models & Simulation

Discrete-event vs Continuous:

- **Example:** Oil tanker loading example: One of the measures of performance is the amount of oil in each tanker.
- Because the oil is a liquid, it cannot be readily divided into discrete components. It flows continuously into the tanker.
- It is not practical to track each molecule of oil individually when you only care about the level of the oil in the tanker.
- In this case, a model of the system must describe the rate of flow over time and the output of the model is presented as a function of time.
- Systems such as these are often modeled using differential equations.

4. Systems, Models & Simulation

Discrete-event Simulation

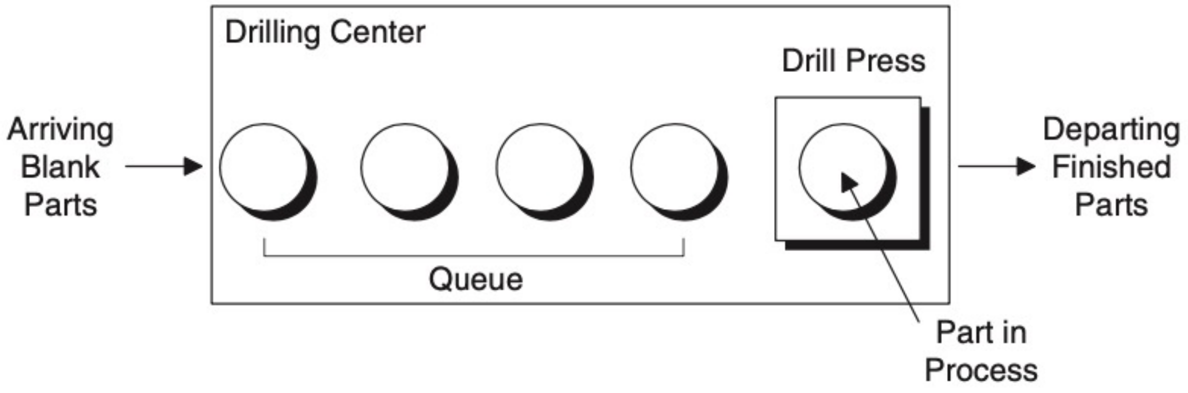
Retail 3-D Simulation on Arena

Pharmacy 3-D Simulation on Arena

4. Systems, Models & Simulation

Discrete-event Simulation

- The most common discrete system is **the queue/server** system.
- Queue/server systems exist whenever a line forms in front of some processing mechanism.
- The line is called a **queue** and the processing mechanism is called the **server**.



4. Systems, Models & Simulation

Discrete-event Simulation

Examples of queueing systems

System	Servers	Customers
Bank	Tellers	Customers
Hospital	Doctors, nurses, beds	Patients
Computer system	Central processing unit, input/output devices	Jobs
Manufacturing system	Machines, workers	Parts
Airport	Runways, gates, security check-in stations	Airplanes, travelers
Communications network	Nodes, links	Messages, packets

4. Systems, Models & Simulation

Discrete-event Simulation

Arrival time vs interarrival time

Part Number	Arrival Time	Interarrival Time
1	0.00	1.73
2	1.73	1.35
3	3.08	0.71
4	3.79	0.62
5	4.41	14.28
6	18.69	0.70
7	19.39	15.52
8	34.91	3.15
9	38.06	1.76
10	39.82	1.00
11	40.82	.
.	.	.
.	.	.