Christmas Lecture

Large Scale Applications of *Concurrent Objects*

-Second Life, Twitter Systems, and Molecular Dynamics Computing-

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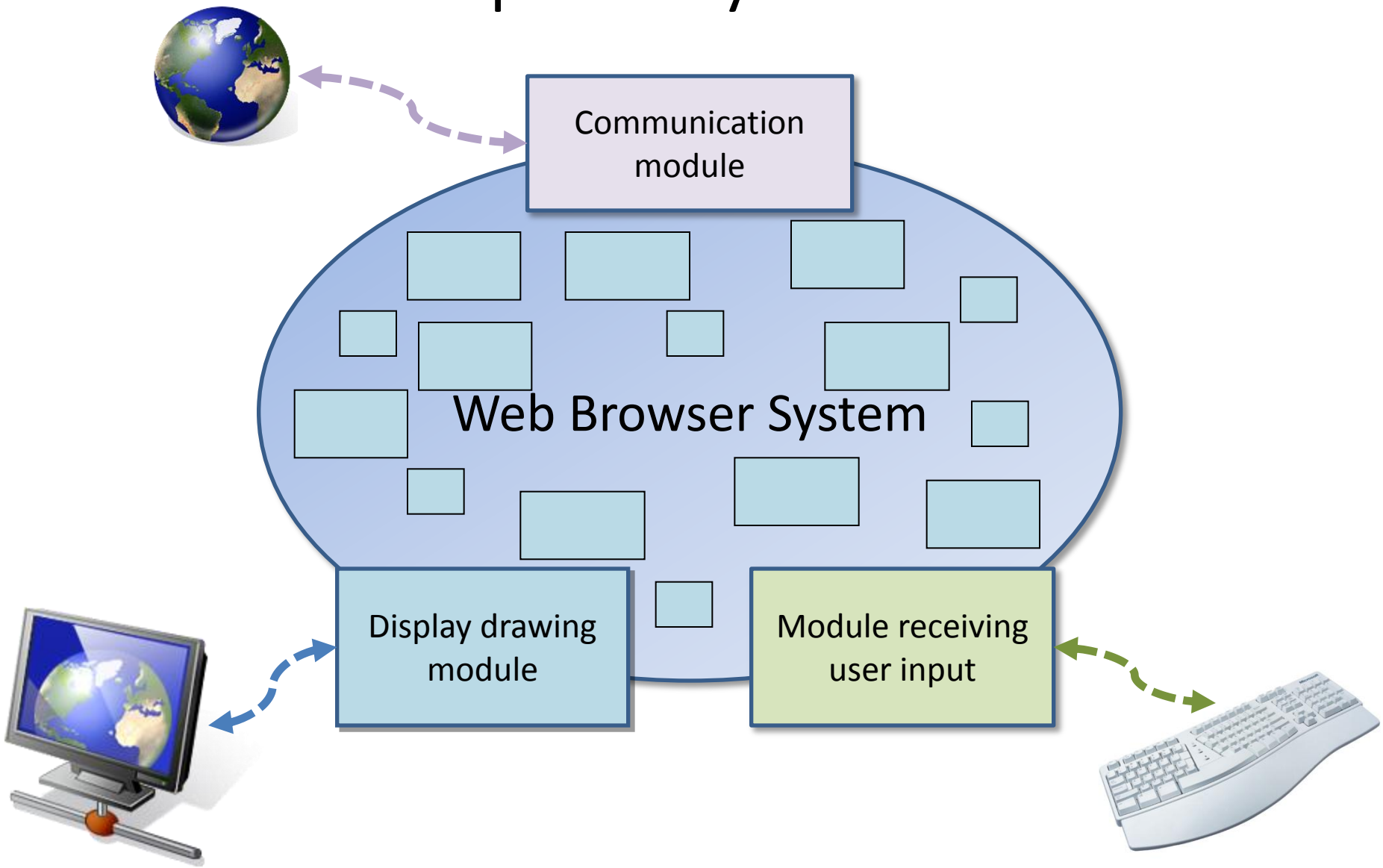
What is this talk all about?

- … talking about a way to construct
  a large software system on
  (massively) parallel distributed computers

A Software System is…

- A software system is composed of many software modules (parts).
  - Just like a car is composed of many physical parts.
- Modules (parts) must be:
  - fairly independent from its surrounding components,
  - composable to form a larger module using other modules
  - replacable by other module with the same functionality
  - etc.

A Software System is composed by software modules..



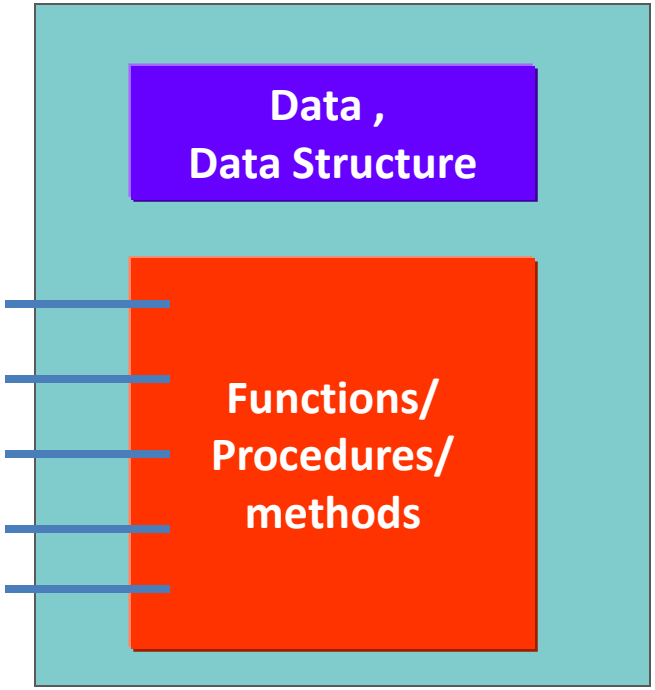
Object:
a form of software modules/parts

- Since 1950's , the following forms:
  - subroutines
  - functions
  - procedures
  - abstract data types
  - etc

- Since the advent of Java language, the "object" form of software module is prevailing in software system construction !!!

What's an Object

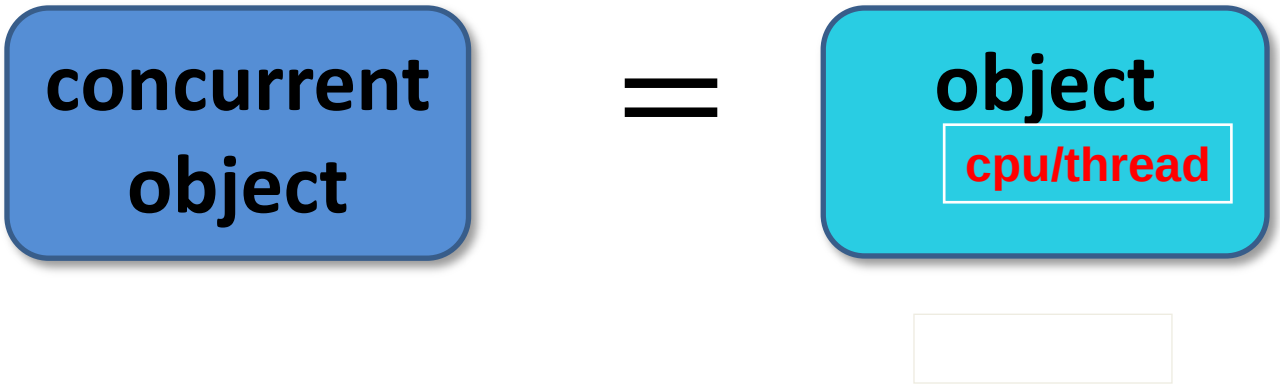
- Data/data-structures and methods using the data are encapsulated together in an Object!!
- An object encapsulates data and methods using the data.



Concurrent Object is a Generalization of Objects!!

I came up with this idea in mid 70's.

Concurrent Object (CO)



1. **CO** encapsulates a statefull object + a singlecpu/thread.

2. **COs** transmit/exchange messages
   concurrently and asynchronously.

Both Modeling and Programming

In mid 70's,I started being interested in:

1. **modeling worlds and**
   simulate them on computers!

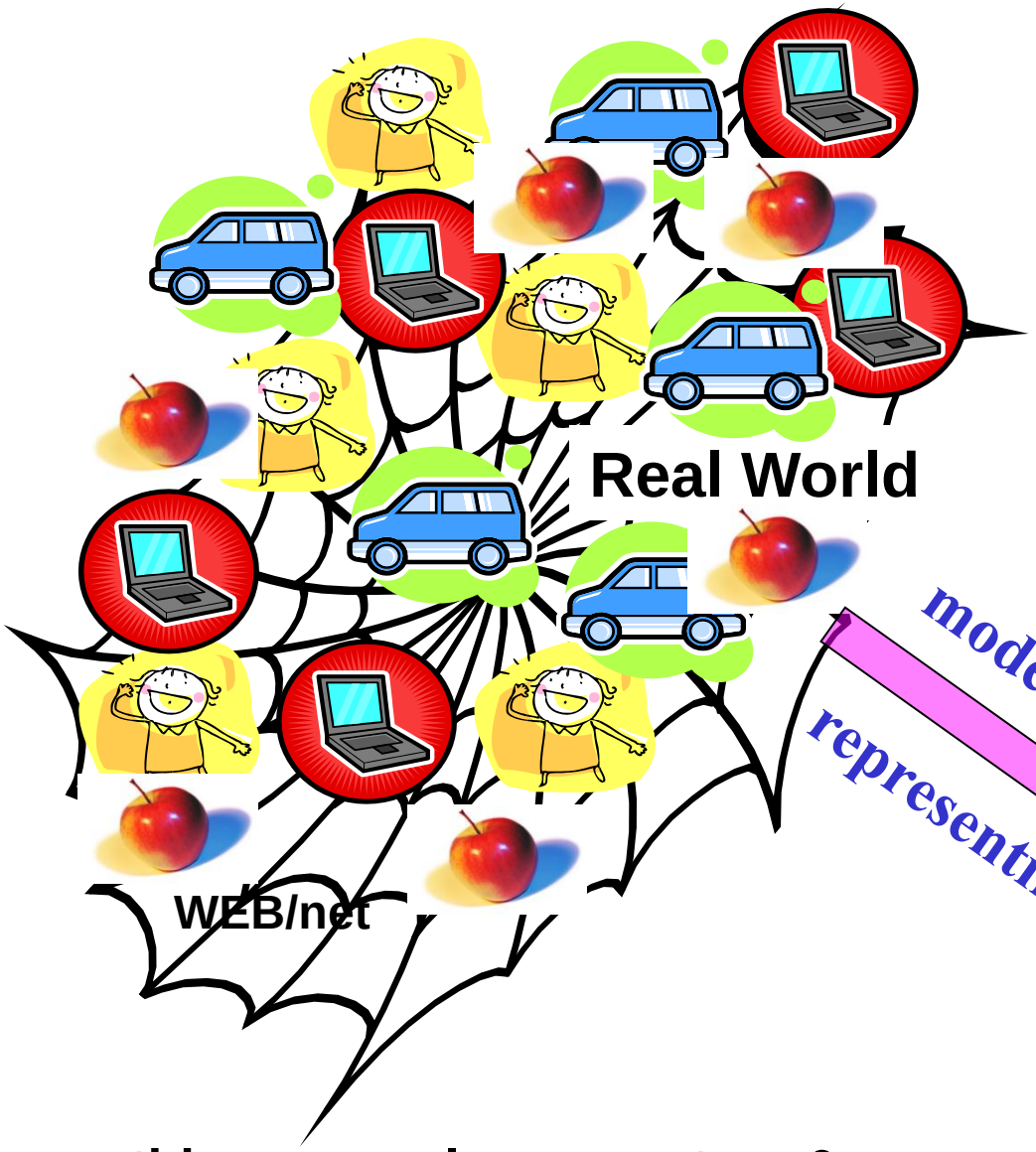
2. **powerful programming frameworks!**

in computer science comm. Of Mid 70's,

- IC is maturing and time-sharing systems are in use
- ARPA Net is expanding…
- A bright future of VLSI was envisaged.
  - C. Mead & L. Conway, *Intro. VLSI Design*, 1979

- Time to prepare ourselves for abundance of inexpensive microprocessors
- Start developing technology for utilize them

My view in 70's:
Modeling and Simulation by Concurrent Objects

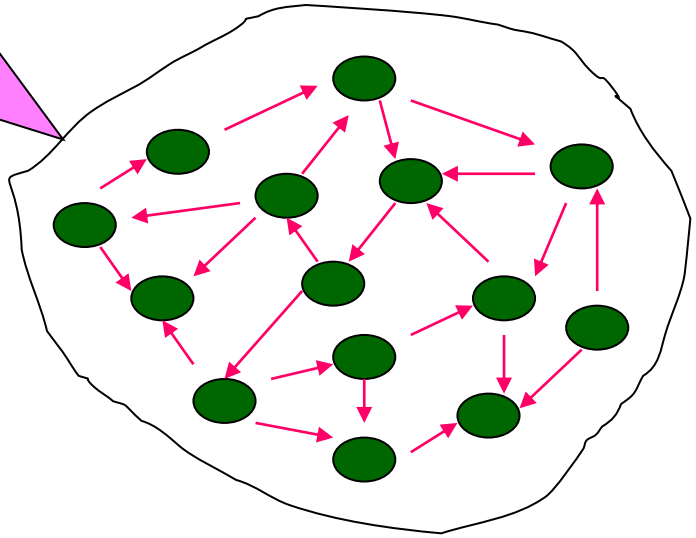


things, people, computers & their interactions

modeling

representing

Concurrent Objects &
their message passing



Crucial Features of Concurrent Objects

1. Message/event-driven activation/processing
2. Asynchronous message transmission
3. Information sharing only through message passing
4. Control flow and message flow coincide
5. Massive parallelism through massive concurrent objects
6. Enables safe use of safe light-weight processes
   - No need for lock/unlock operations

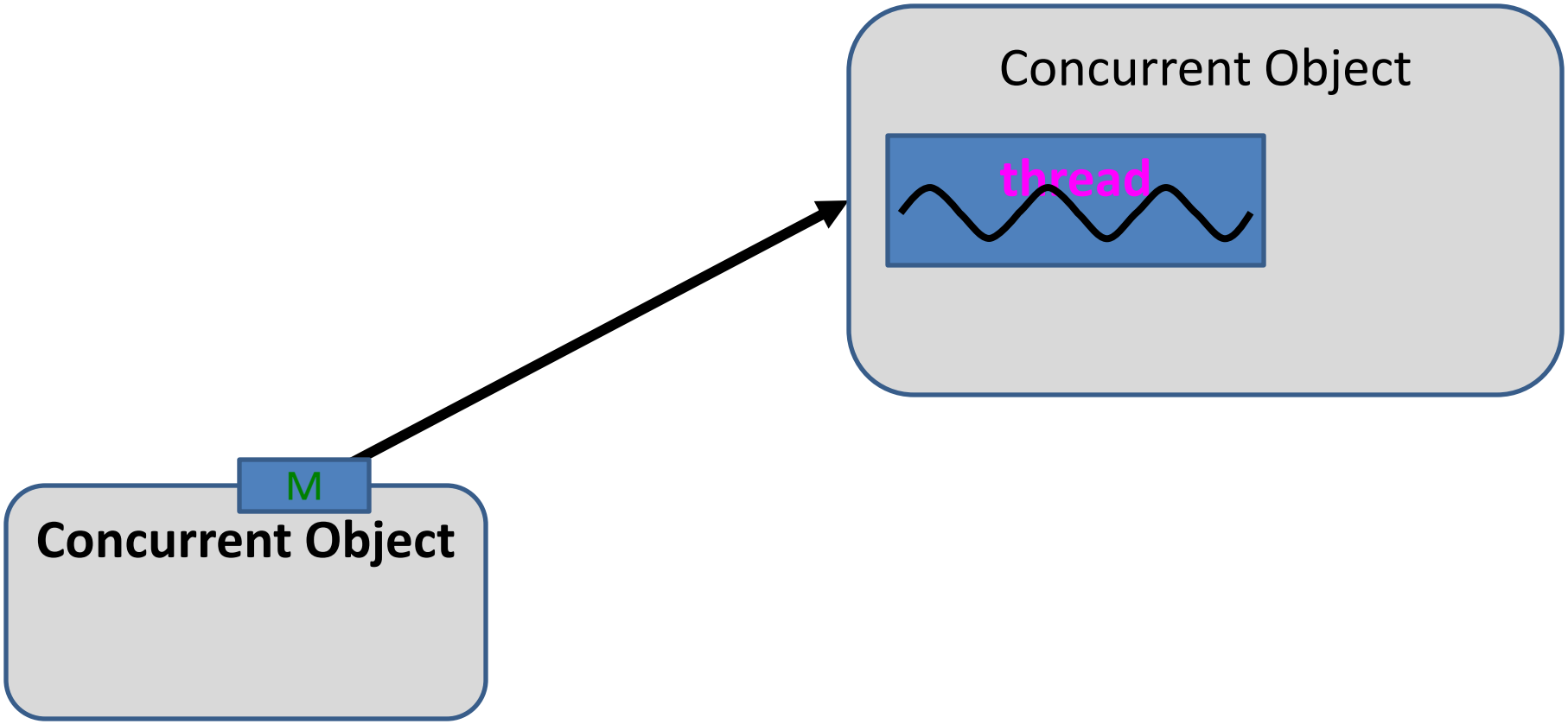
Parallelism in a domain/world can be naturally/directly modeled with COs

In domains,

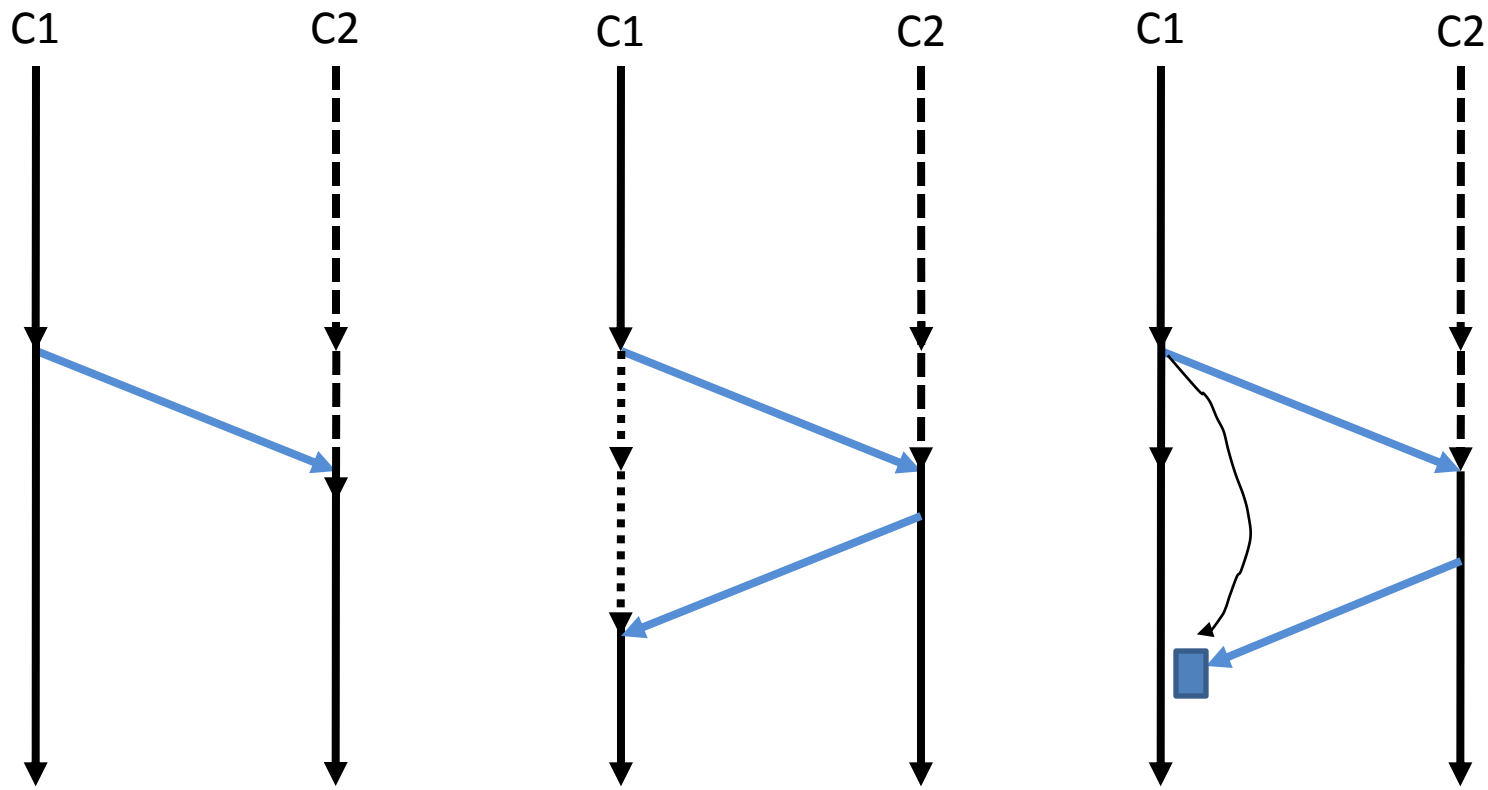
- Rain drops fall in parallel.
- Things exit in parallel.

- Parallelism by an ensemble of many COs
- State change of a thing is reflected by state change of the CO.
  - COs move in V-space as things moves in space.
- COs interact with message transmissions as things interact.

1. Message/Event Driven



2. Asynchronous message passing

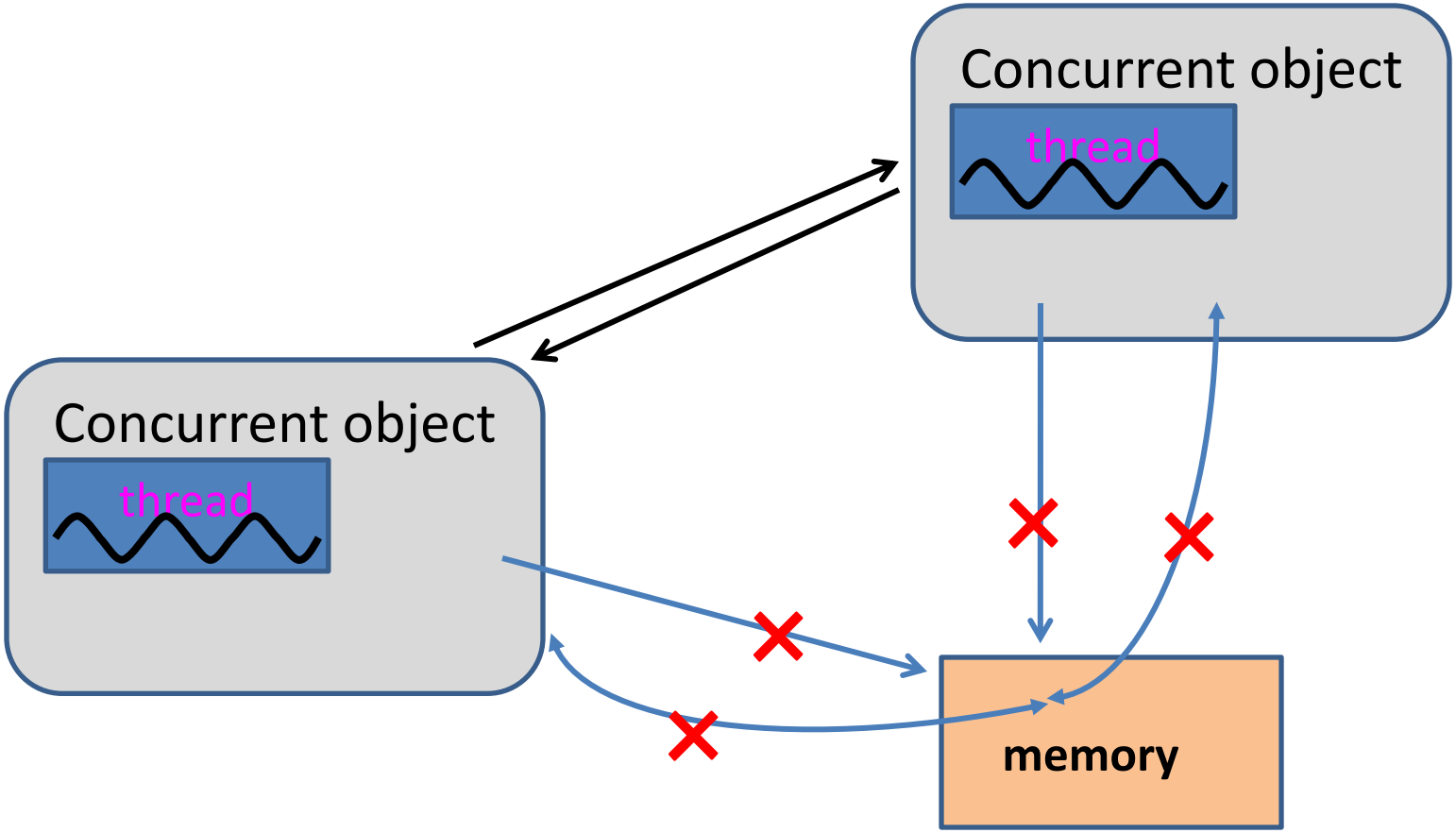


Type1

Type2

Type3(future)

3. Information sharing is possible, only through message passing,

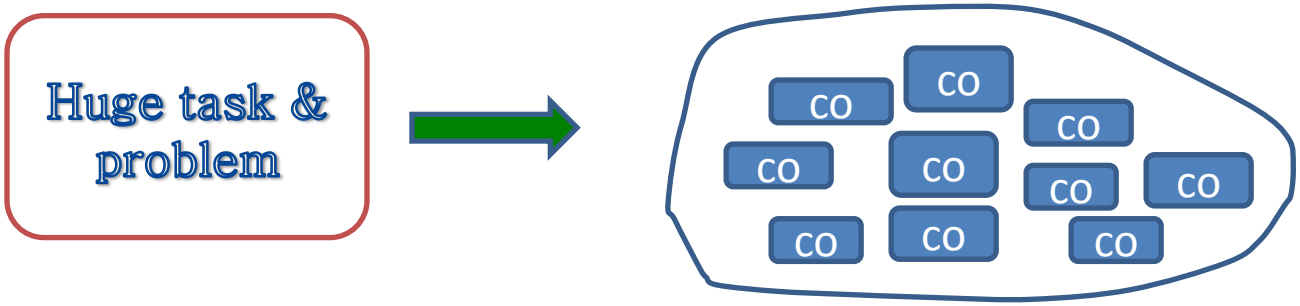


What can be modeled and represented by COs

- Mass, particle、structures
- Human, agent,

More abstractly…

- Virtual processor（VP）, light-weight thread
- Fine parts and processing units obtained by partition of large problem



Large Scale Applications of COs

1. Second Life system
2. Twitter system
3. NAMD, a nano-bio molecular dynamics simulator for supercomputers

Which CO's advantages enable large scale applications?

1. Natural modeling power

Second Life -- simple and powerful description

2. Parallel programming
   with safe high performance

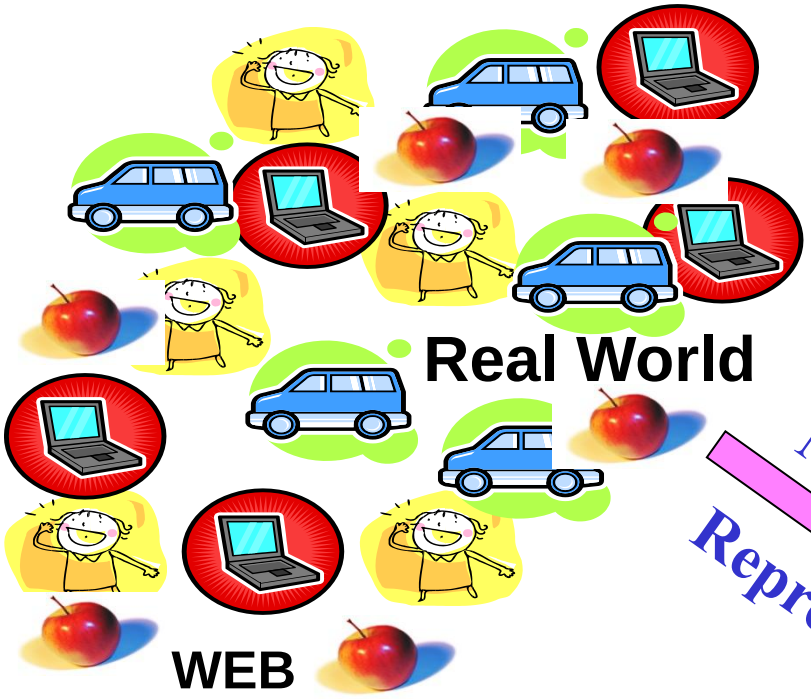
Twitter, Facebok

3. Parallel programming
   with high performance and high productivity

Charm++ → **NAMD** → analysis of molecular structures of **Swine Flu**

Second Life

Back to Original Motivation of COs

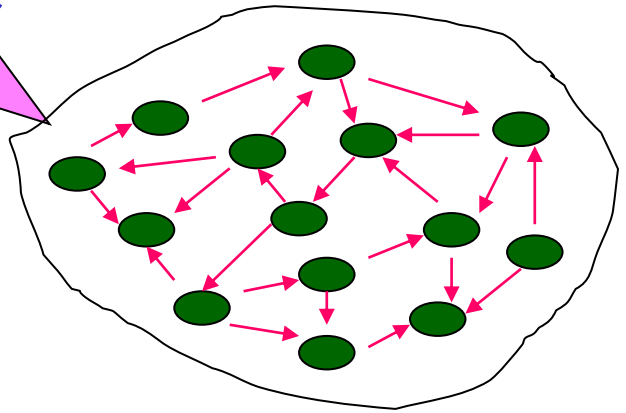


Modeling

Representing

Concurrent Objects &

Message Passing



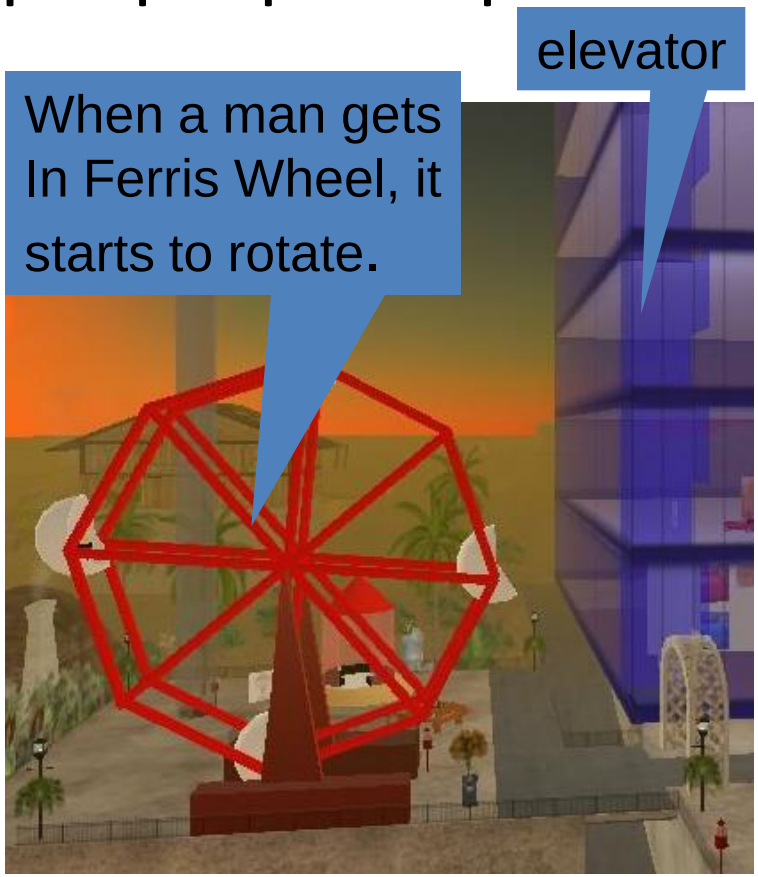
Entities,people,
machines &
their interactios

Linden's *Second Life* …

is a natural outcome from the motivation of Cos.

Concurrent Objects in Second Life

- Linden's online Virtual World that millions people participate in!



- Objects and avatars are represented and programmed as *concurrent objects!!*

Image from "Programming Second Life with the Linden Scripting Language" by Jeff Heaton (http://www.devx.com/opensource/Article/33905)

COs in Second Life

- Jim Purbrick, Mark Lentczner,

  "Second Life: The World's Biggest Programming Environment",

  Invited Talk at OOPSLA2007, said:

  - Objects and avatars cooperate and coordinate each other by exchanging messages.
  - each object or avatar is programmed to
    - **Have its own state,**
    - **Have its own method to respond to an incoming message,**
    - **Have different responses to different states, and**
    - **Have its own thread.**

    } COness!
  - About 2 millions of objects are programmed in Second Life and they are in action.

Second Life Teleporting Demo

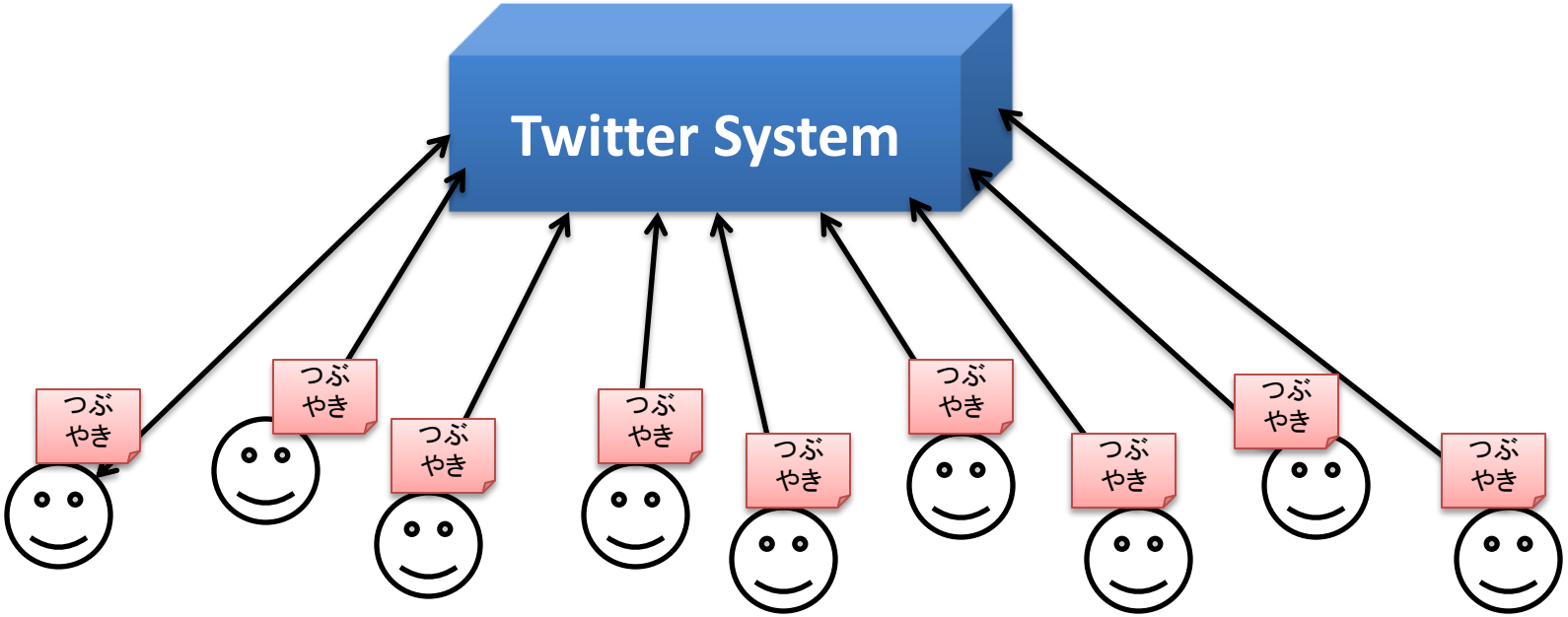
テレポート（4次元での移動）する

Twitter

Joichi Ito (伊藤　穰一）talks about Twitter

Twitter System

Over 100 millions people are using it



COs in Twitter

Implementing Twitter System requires:

a huge number of twitters need to be processed in parallel.

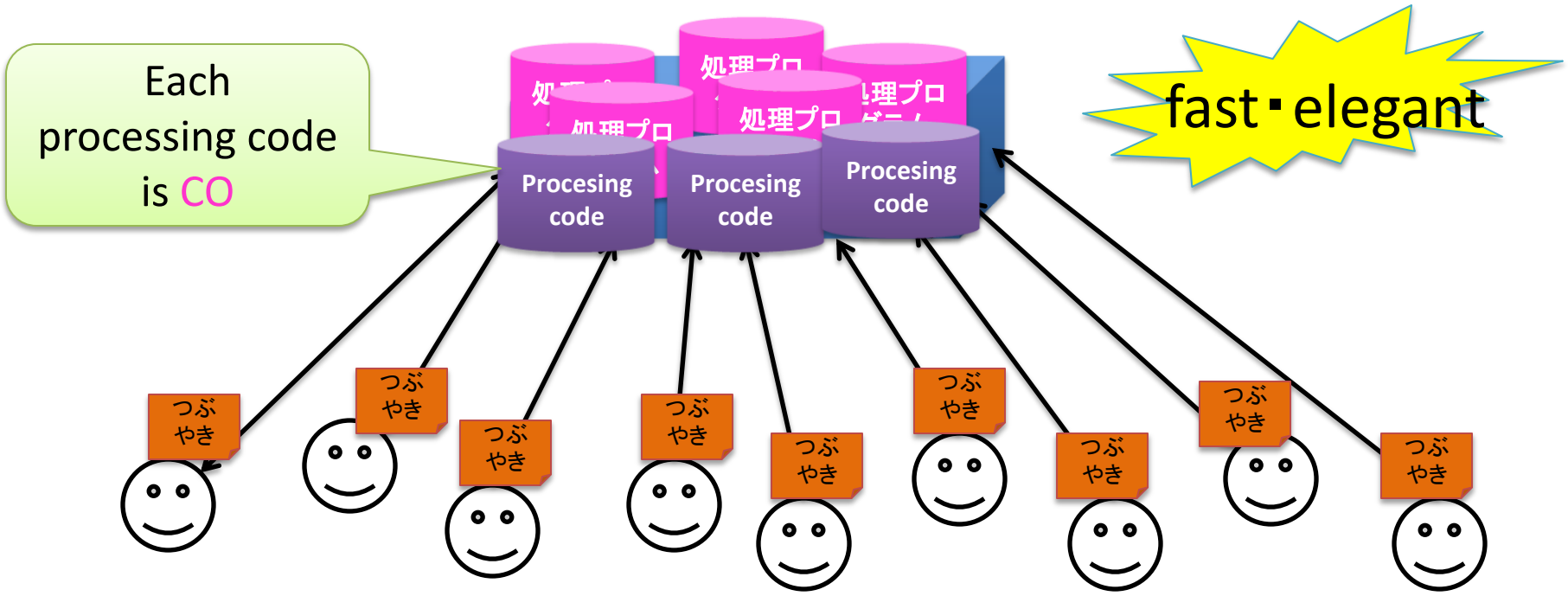
accomplished by using a huge number of COs!!

The CO/actor mechanism in Scala language is employed!

Ruby on Rails was used in an old version of Twitter.

Implementation of Twitter System

- Requests from clients are processed by COs
- a large number of twitters are processed by a large number of COs
- COs enable a simple construction of the stable and fast system.



Why COs are Used?

Robey Pointer says:

When a client logins, a CO is created and waits for twitters to come.

- Use of COs makes the program very simple!!
  - owing to the nature of message-driven and asynchronous messages
  - Krestel (Core of the system) is written by 2000 lines of code
- Enables fast processing, and load balancing

  (At peak, 10 thousands twitters are processed)
  - a huge number of COs make load balancing possible
- No more than one thread is contained in a single CO.
  - Lock/unlock operations are unnecessary!!!
- Handling the twitter queue is possible by a large number of threads for an ordinary load, but still difficult and unsafe for lock/unlock operations --- Program safety is hard to gurantee!!

KESTREL
(http://github.com/robey/kestrel)

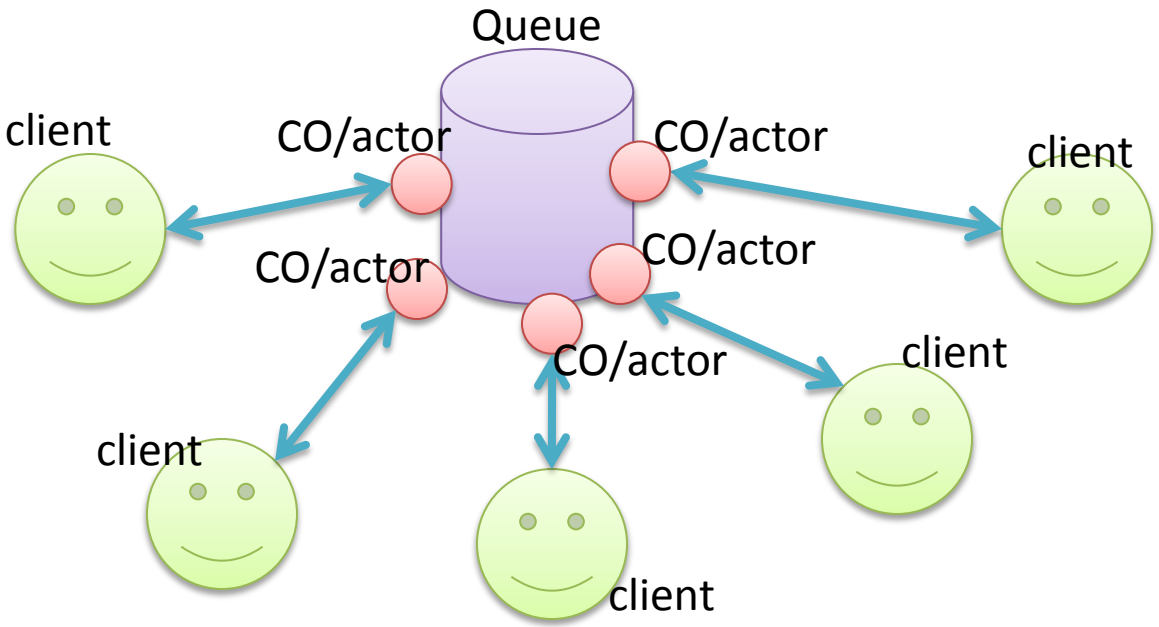
- Core software modules in Twitter System
  which handles client messages(twitters)
- Used as backend for Twitter System
  http://blog.twitter.com/2009/01/building-on-open-source.html

Kestrel

- Message queue hand system written in language Scala
  - CO/actor facilities supported in Scala are extensively used.
  - The code is only 2000 lines long!!
  - Tens of thousands of parallel processing by CO/actors

Scheme of Kestrel

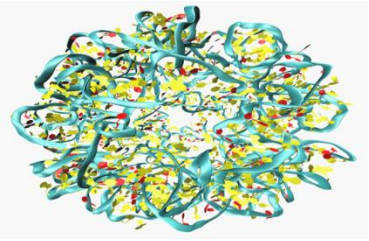
- Requests from clients are processed by CO/actors
  - For each client, a CO/actor is dynamically created.
  - E.g., 7000 CO/actors for 7000 login clients in parallel



NAMD

(Nano-scale Molecular Dynamics Simulator)

NAMD[1996]

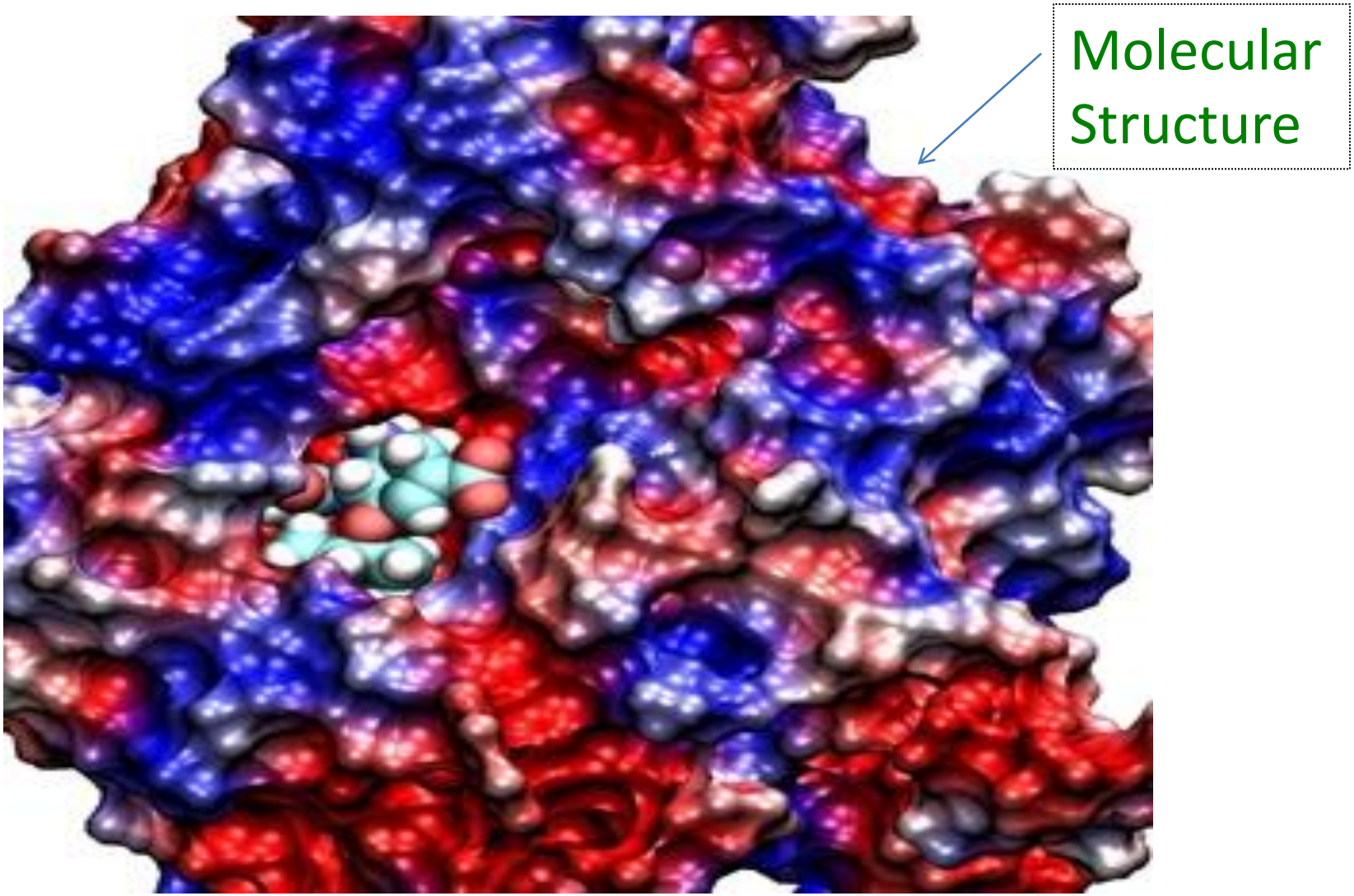


- Nano scale molecular dynamics simulator for supercomputers
- Received Gordon Bell Prize in 2006
- Developed jointly by two groups in Illinois Univ.
  - Prof. Sanjay Kale (Computer Science)
  - Prof. Schulten (Theoretical Biology)
- Written in Concurrent Object-based system Charm++

"**NAMD** is a parallel, object-oriented molecular dynamics code designed for high-performance simulation of large biomolecular systems."

- Simulate step by step, each step representing 1 fs.
- At each step, calculate forces exorted on all molecules and update their positions and velocities

This still from a Quicktime movie represents a view of the drug buried in the binding pocket of the A/H1N1 neuraminidase protein.



Charm++[1993]

- CO-based language system for parallel/supercomputers developed by Prof. Kale.
  -- many references to our CO-based language ABCL
- Used for development of NAMD, OpenAtom（quantum chemistry）, ChaNCA（Galaxy generation）
- Operational for machines with 1000~10000 CPUs
- Has a framework for dynamic load balancing by moving Cos from node to node
- Applications written in Charm++ are
  – Utilizing and consuming 15%~20% of computing resources intwo major supercomputing centers in US

Goals of Charm++

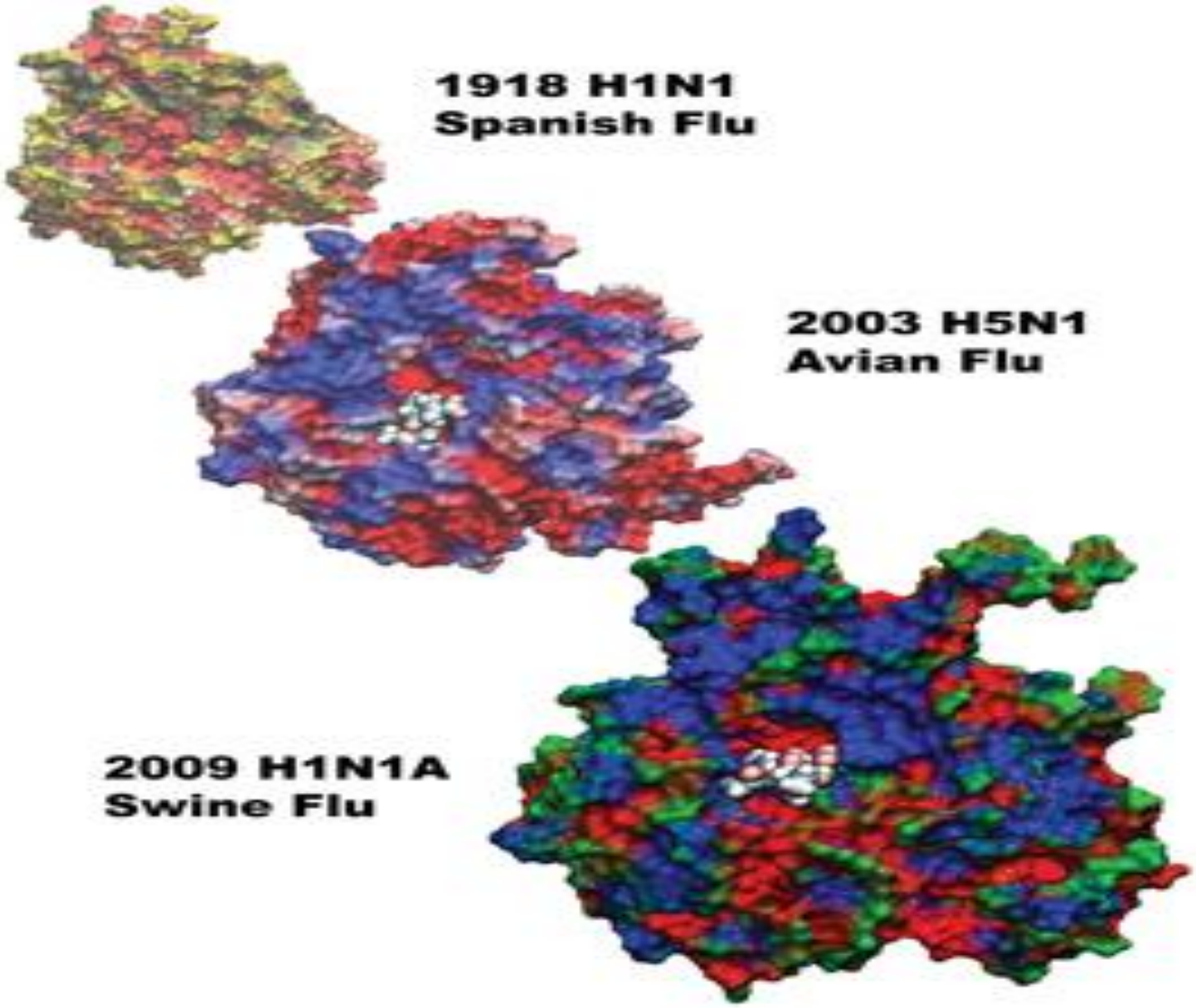
CO-based programming system for supercomputers
http://charm.cs.uiuc.edu/

- Goals:
  1. **Improve performance of parallel applications for regular and dynamic problems**
  2. **Improve productivity of programmers an programming**

Analysis of Molecular Structure of Swine Flu by NAMD

Showed:

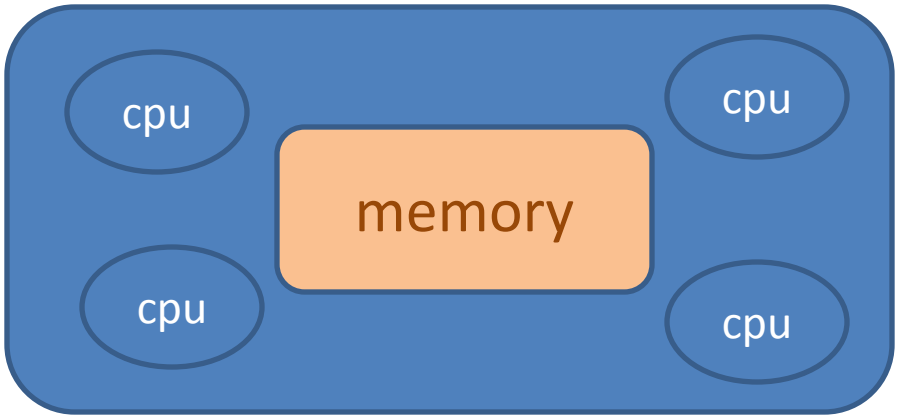
- Structural changes of A/H1N1 protein induce anti-tamiful effects.


1918 H1N1
Spanish Flu
2003 H5N1
Avian Flu
2009 H1N1A
Swine Flu

Towards Many-Core Machine Era

Multi-Core (Many-Core) Chip

- 4 ~ a few hundreds of CPUs on a single chip



- Laptop with 30~40core machine, in 5 years

New Type of Supercomputers

- 100K ~ 1000K machines (node) connected each other!!!
- Each node contains 16> cores

How to Program Many-Core Machines and Supercomputers

- Programming easily and efficiently is

  a big problem!!

- Main problems:
  - Synchronization between processes(CPUs)
  - Communications between processes
  - Deadlock avoidance
  - Developing parallel algorithms

A Solution

- *Concurrent-Object based Programming (CO)*

  Concurrent Object-Oriented Programming(COOP)

End