Emerging risks in complex systems - discovering risks in complex system by intelligent simulation of their behavior

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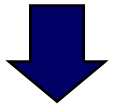
To Simulate a Human Society

- We must consider two kinds of non-linearity
  - Human being with intelligence
  - Social phenomena as a result of interaction among of individual behaviors



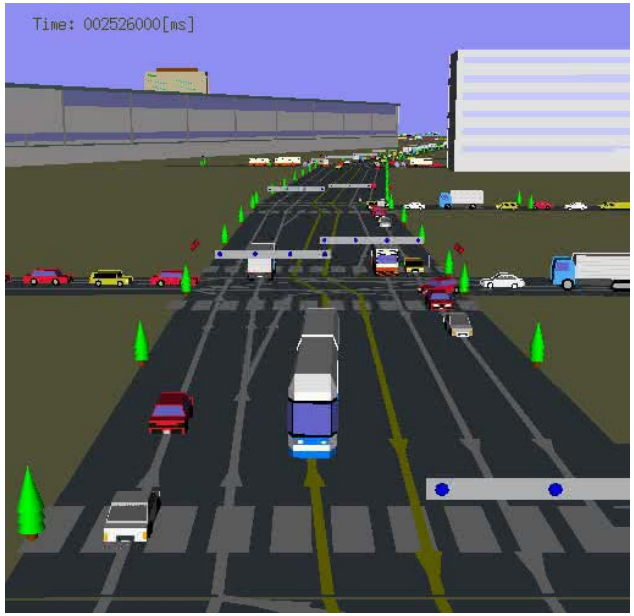
Both of them play key roles in risks in social systems,
but conventional simulations deal with one of them.

- Requirements for social system simulations
  - Precise modeling of each human being with intelligence
  - Mechanisms to express the complexity of social phenomena

Our Approach to Advanced Traffic Simulation

- Traffic system
  - A key portion of infrastructure to support mobility and transportation of human beings and goods.
  - Including various kinds of risks (e.g. traffic accident)

- Features for quantitative evaluation of risks
  - Traffic system as a complex system
    - Using multi-agent system
  - Precise driver model
    - Recognition error model



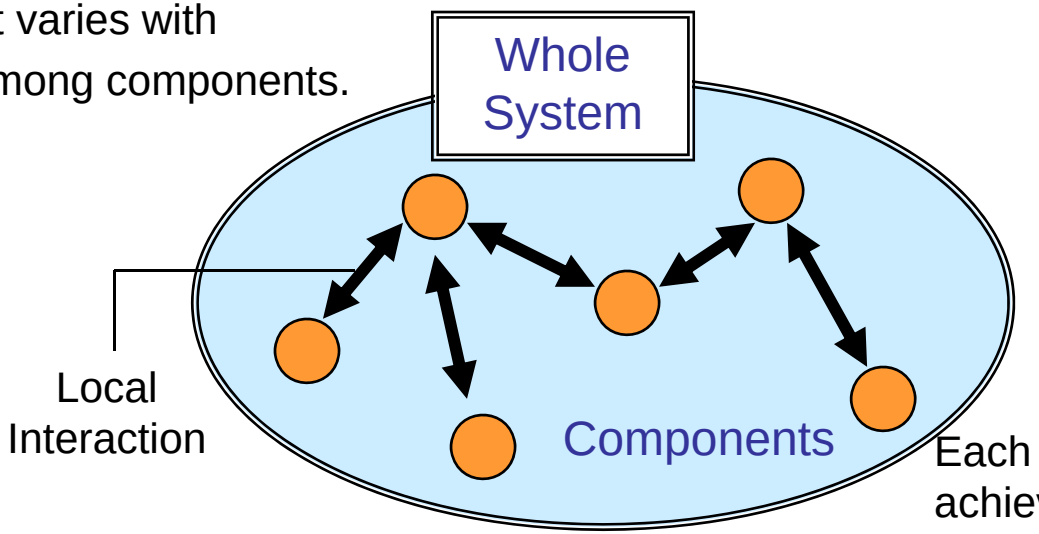
MATES
Multi-Agent Based Traffic
and Environment Simulator

Modeling of Traffic Flow (1)

- Concept of traffic phenomena in MATES
  - Each component (e.g. a car) follows relatively simple traffic rules.
  - Through the interaction of many components, macroscopic traffic phenomena present very complex behaviors.

Traffic system as a complex system

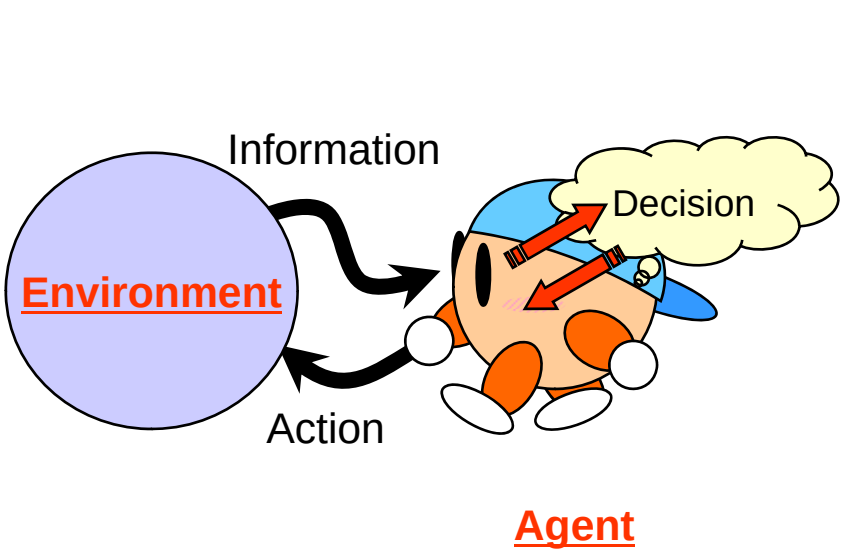
Whole context varies with interactions among components.

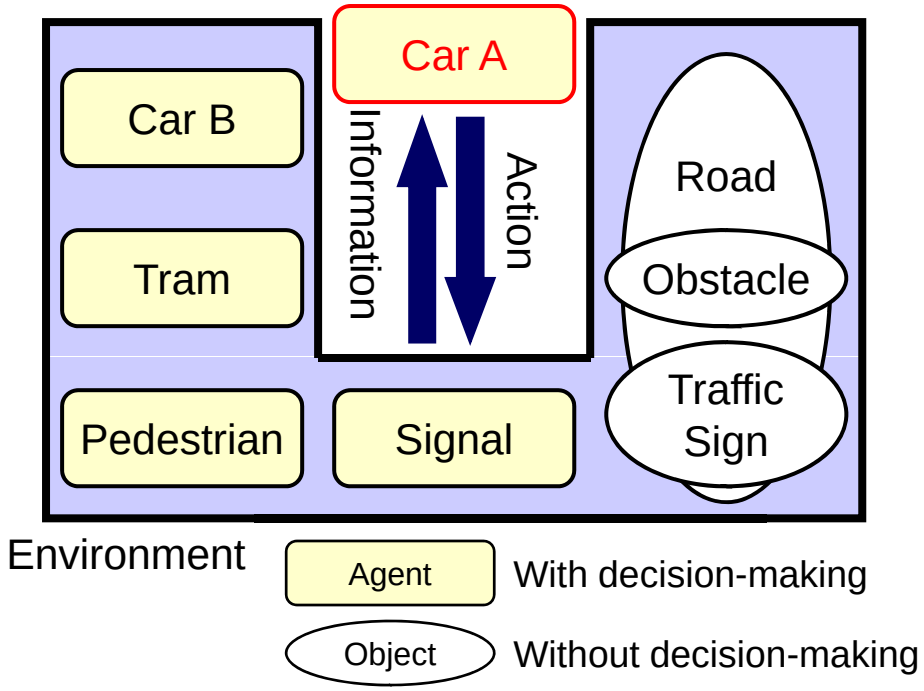


Each component tries to achieve its objective by adapting itself to changing context.

Modeling of Traffic Flow (2)

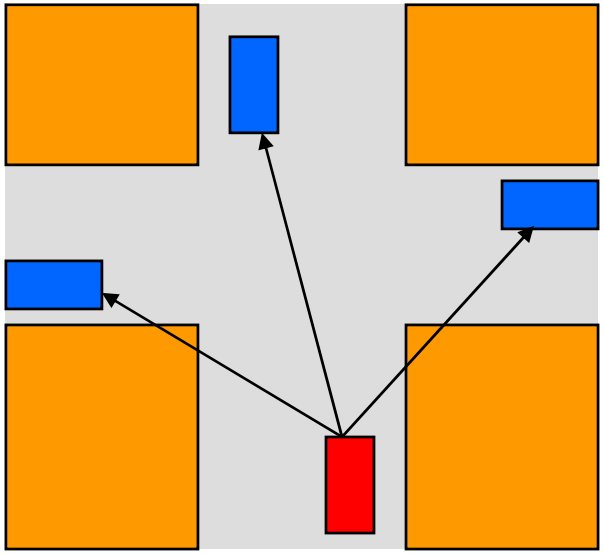
- Multi-agent system
  - One of successful methods to model complex systems.
  - An agent gets information from the environment, makes a decision by itself, and acts according to the decision.
  - For an agent, other agents are parts of the environment, so agents interact with each other through the environment.
  - Complex traffic phenomena emerge as a result of the sum of interactions.



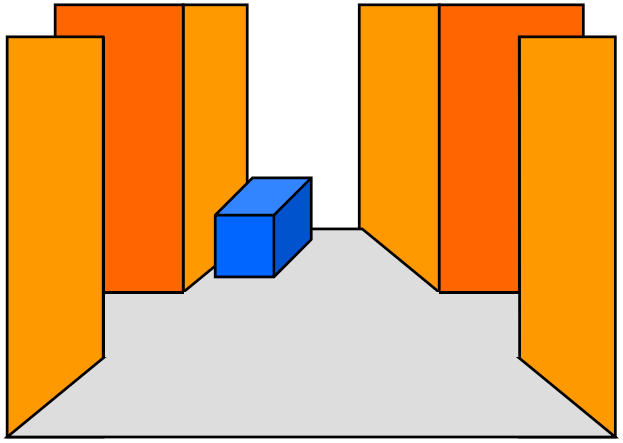


Recognition Error Model (1)

- Traffic accident simulation
  - A traffic accident occurs when a car driver overlooks something to watch (other cars, pedestrians, traffic signals, obstacles, etc.) .
  - In most simulators using a multi-agent model, an agent can recognize everything around it instantly and correctly.
  - To evaluate the incidence of traffic accidents quantitatively, we must construct drivers' recognition error (overlooking) model.



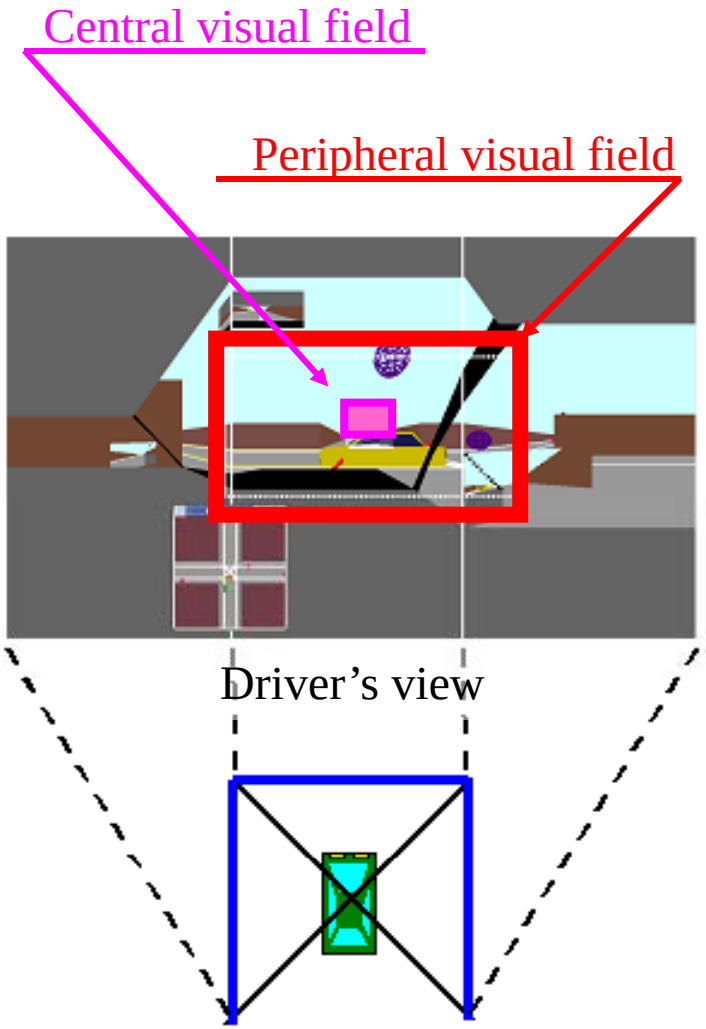
Simulation



Real world

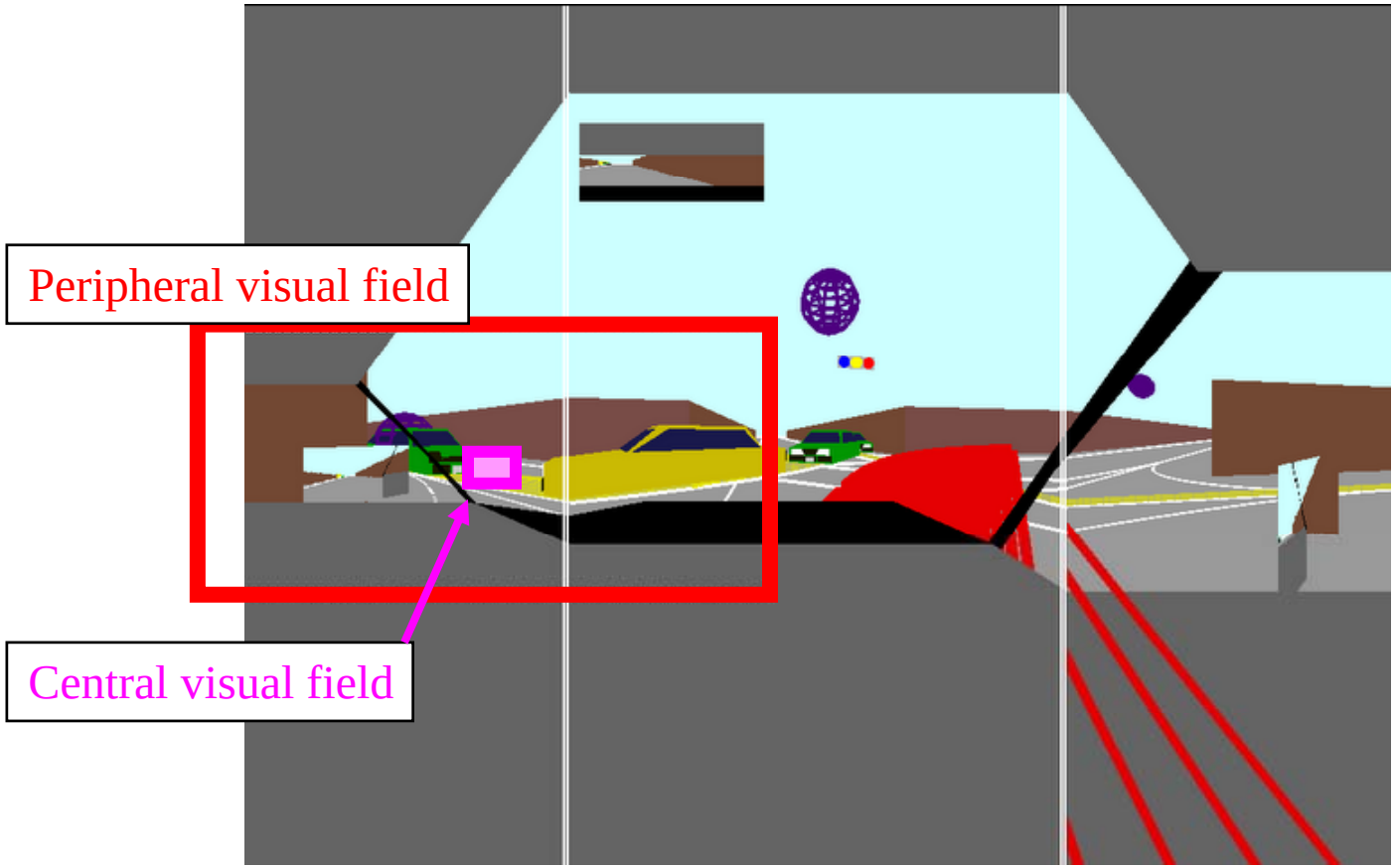
Recognition Error Model (2)

- Central and peripheral visual field
  - A driver agent has central visual field and peripheral visual field.
  - The size of peripheral visual field is set to be 130 degree long and 200 degree wide.
  - A driver moves its central visual field to the object that occupies the largest area in its peripheral visual field.
  - A driver can recognize the object only in its central visual field.
  - According to the result of this recognition process, a driver decides its behavior. (acceleration/deceleration etc.).



Simulation Screenshot

Driver's View
- This driver will turn right at the next intersection.



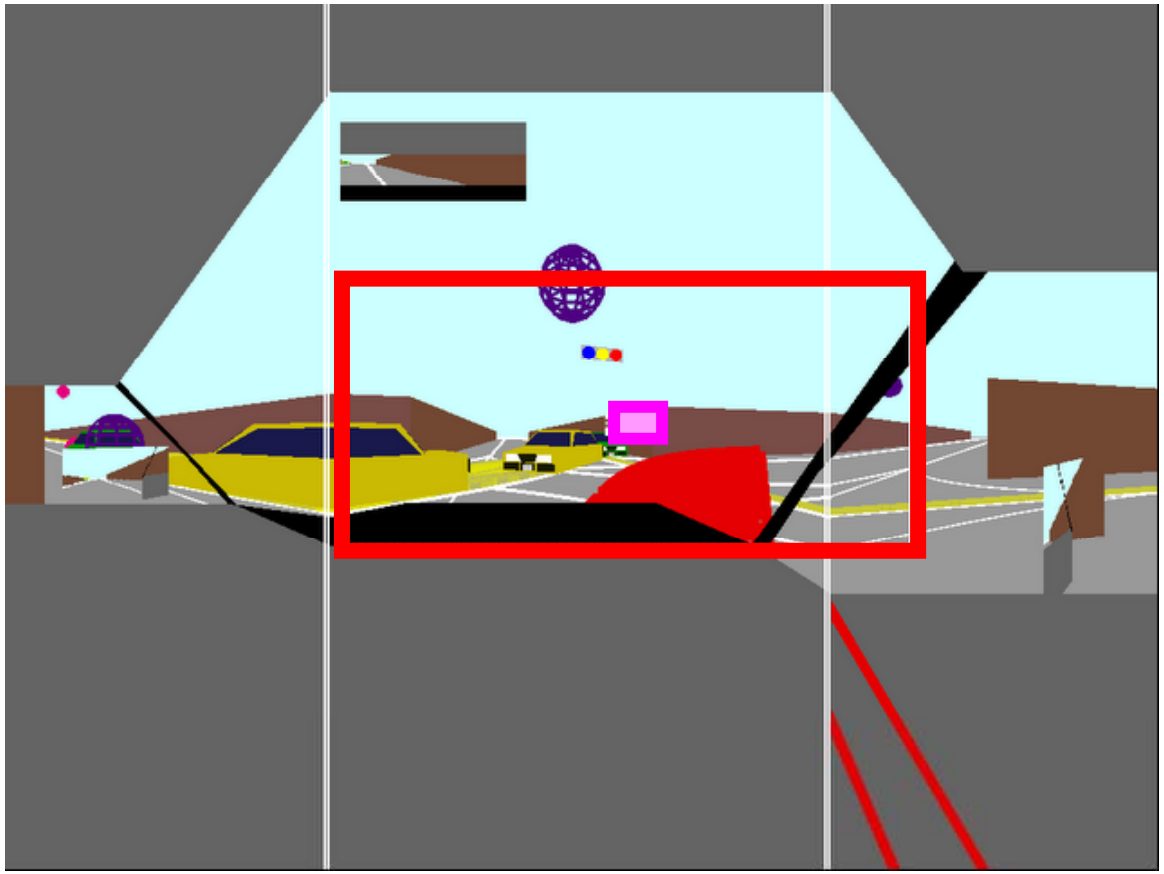
* In Japan, people drive on the left.

- Yellow car: Already recognized
- Green car: Not recognized yet

Simulation Screenshot

Driver's View

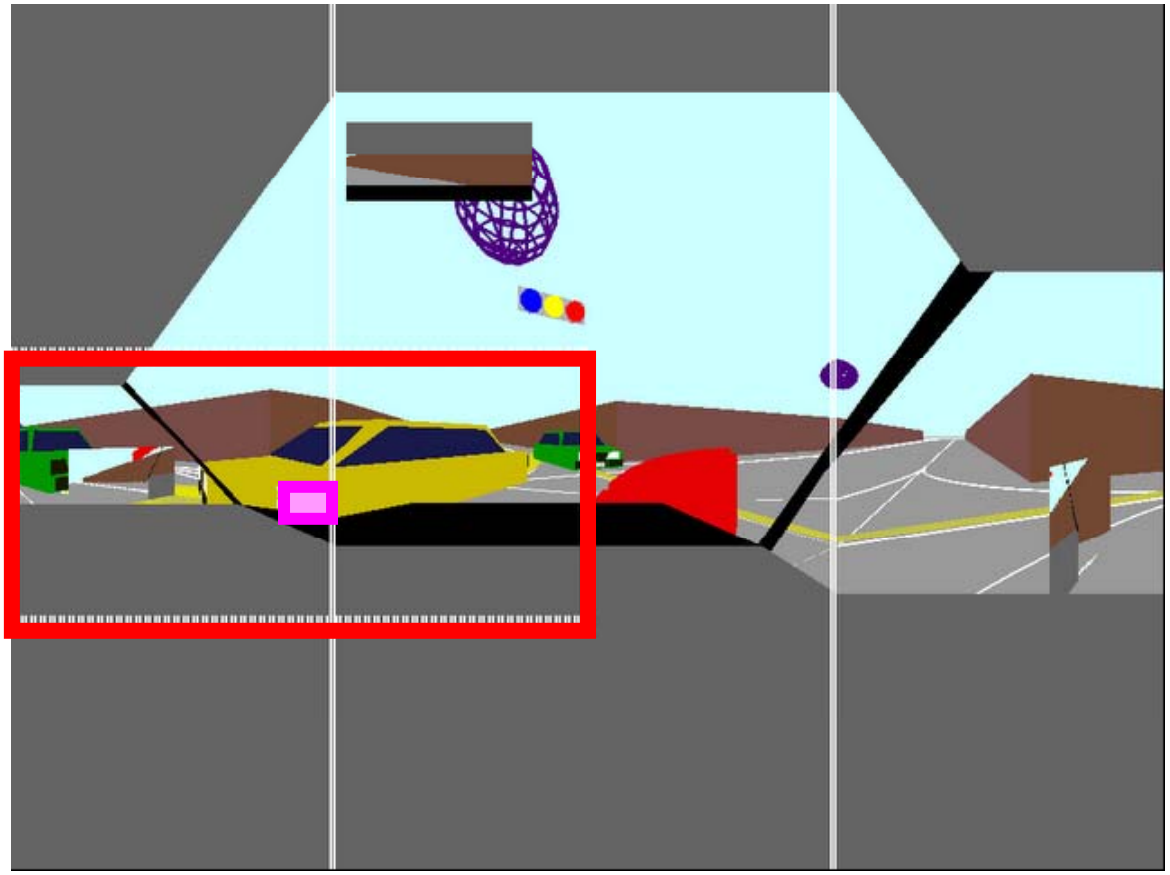
- The driver just recognizes the next car.



- Yellow car: Already recognized
- Green car: Not recognized yet

Simulation Screenshot

Driver's View

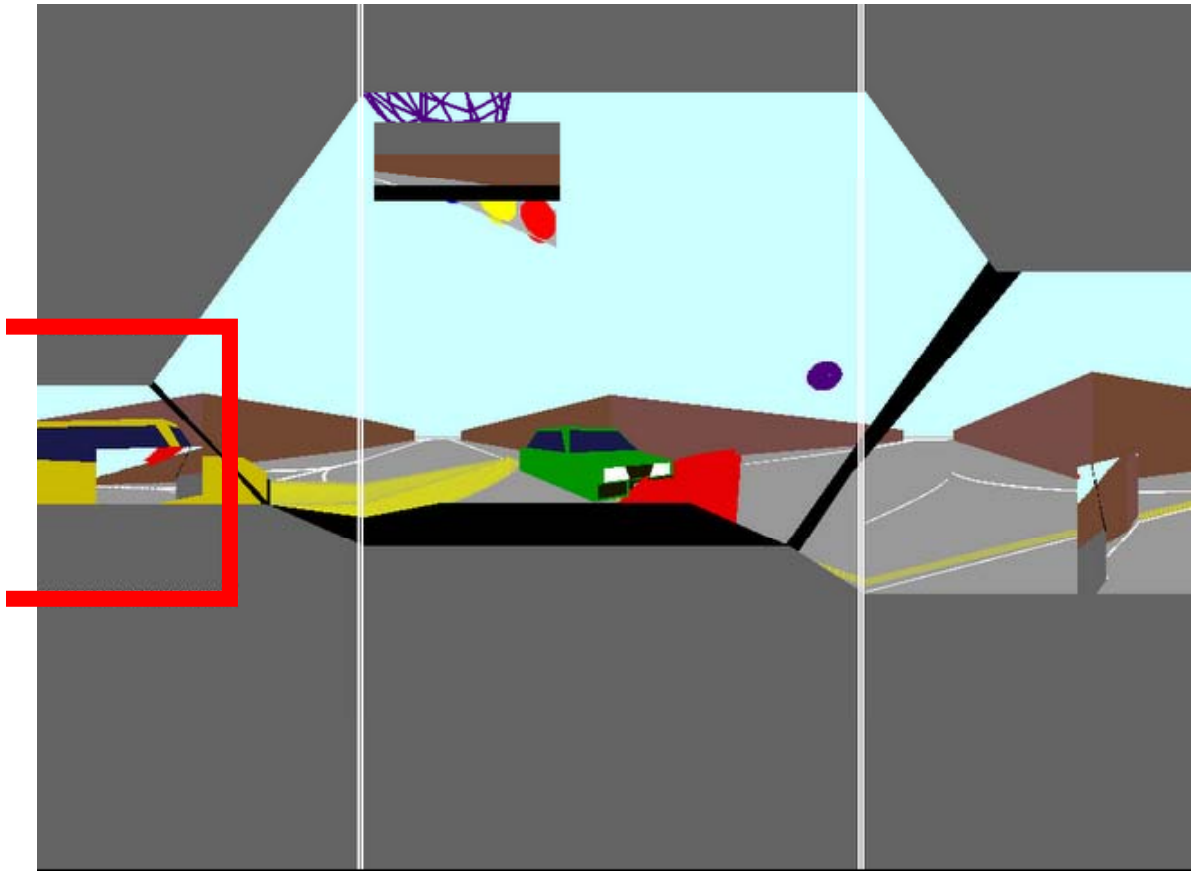


- Yellow car: Already recognized
- Green car: Not recognized yet

Simulation Screenshot

Driver's View

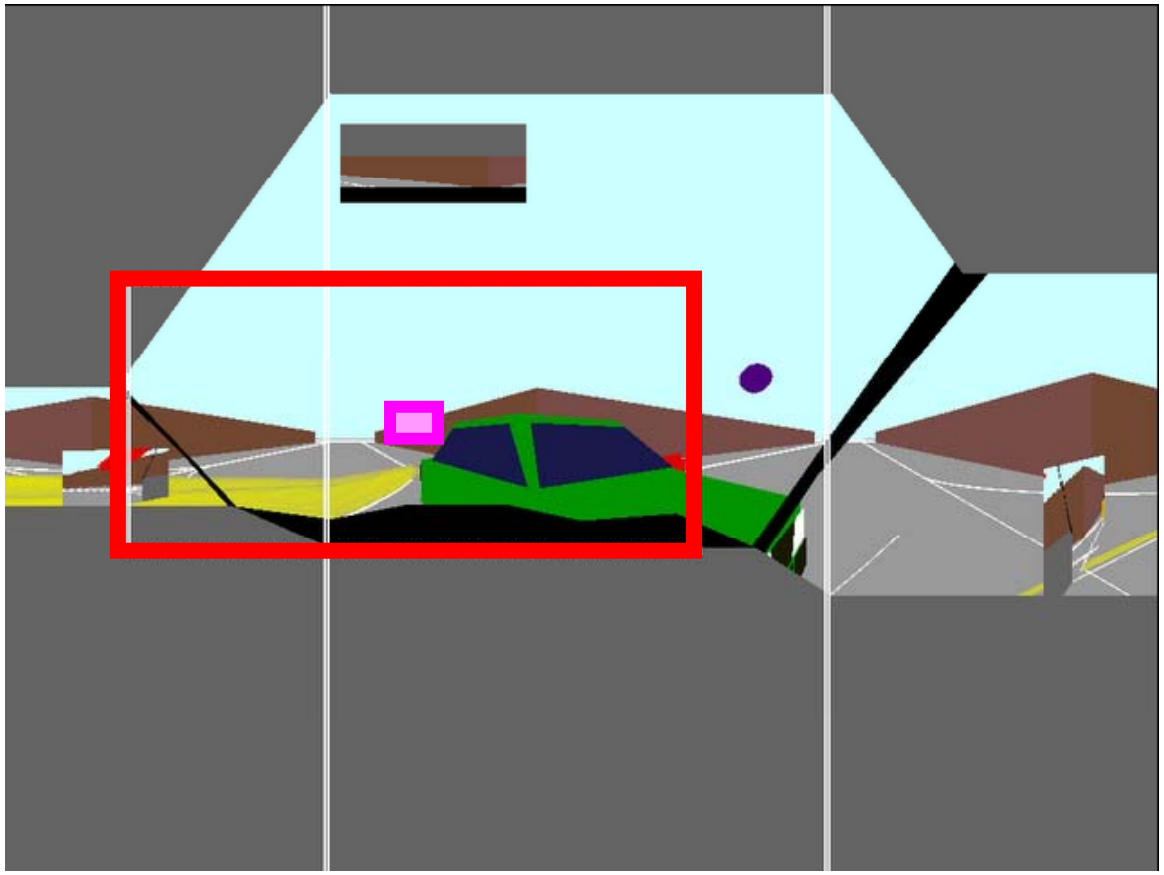
- The driver keeps looking at a passed car, and overlooks the next car.



- Yellow car: Already recognized
- Green car: Not recognized yet

Simulation Screenshot

Driver's View
- Unfortunately, they crashed.



- Yellow car: Already recognized
- Green car: Not recognized yet

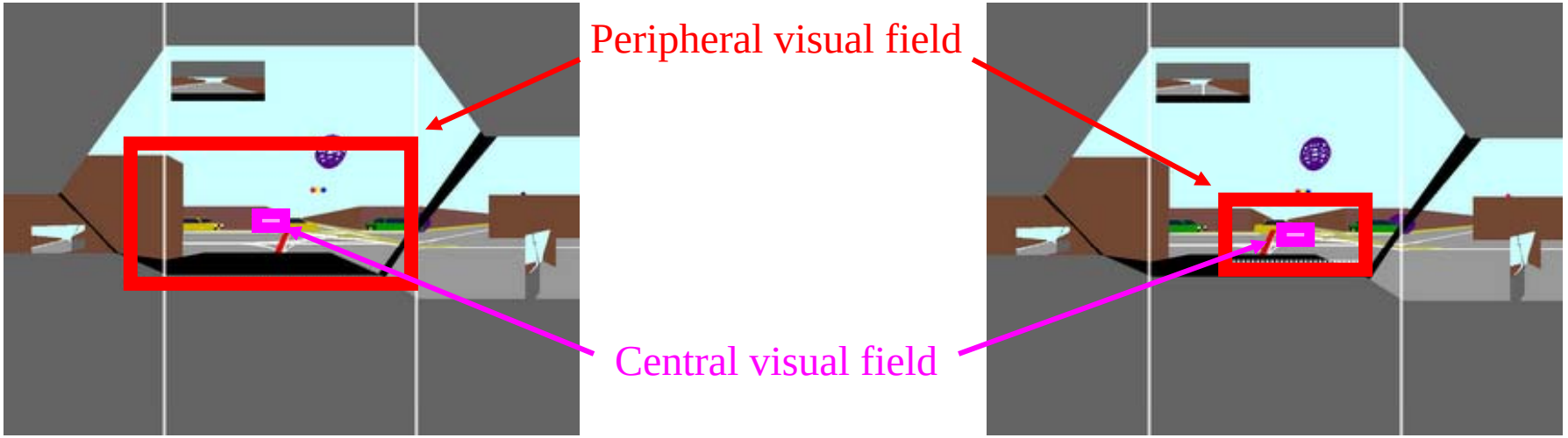
Applications (1)

- Risks for elderly driver
  - In Japan, due to a highly aging society (the aging rate is 22% today), the increase of traffic accidents caused by elderly drivers is becoming one of social issues.

Their Visual field is narrower than young drivers

➡ Overlooking more objects

➡ The incidence of traffic accidents increases

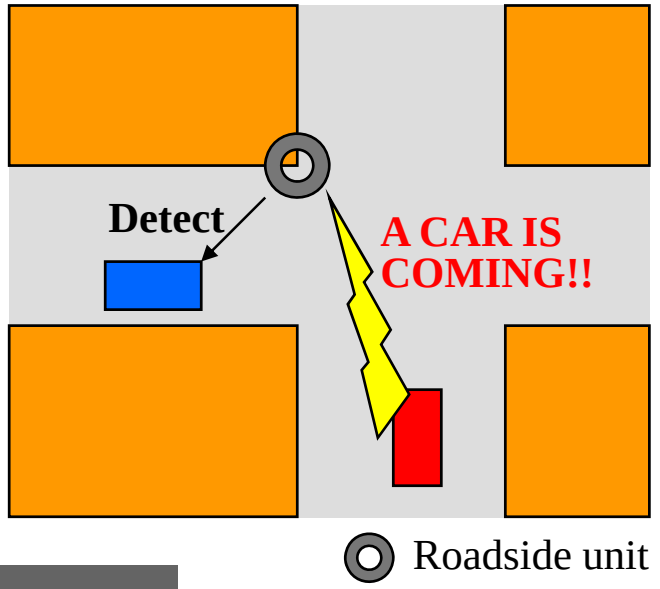


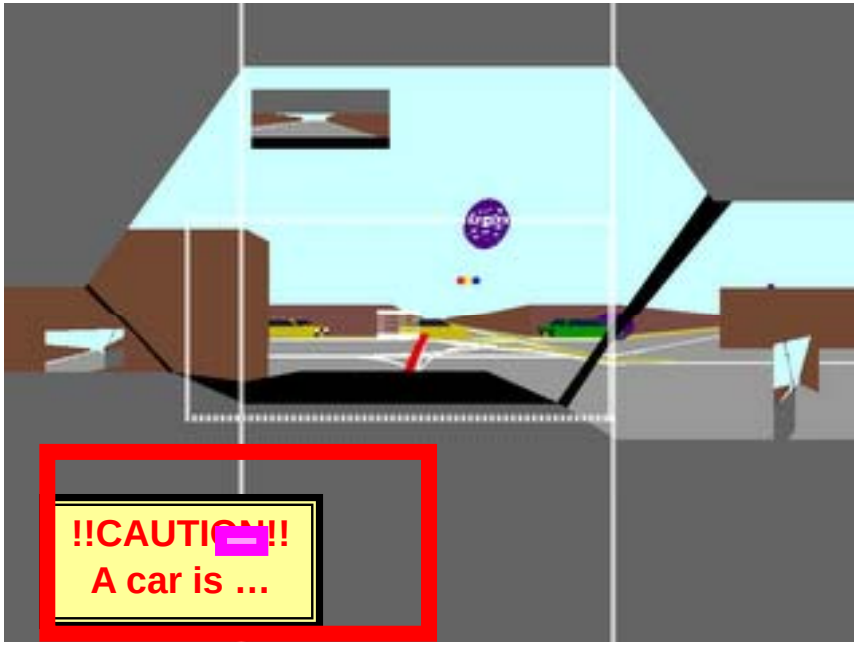
Young driver

Elderly driver

Applications (2)

- Benefit and risks of ITS (Intelligent Transportation Systems) technology
  - Vehicles communicate with roadside unit to reduce traffic accidents.
  - A driver can recognize other cars or pedestrians in blind corners through the ITS device in the dashboard panel.
  - When a driver looks the device carefully, …





Driver's view with ITS device (Sample image)

Conclusions

- We must consider two kinds of non-linearity to simulate social systems.
  - Human being as a component of social system
  - Social system as a complex system

- We have developed a new simulation system that includes both of them.
  - Using multi-agent system
  - Implementation of recognition error model
    - Driver has its own visual field, and overlook objects outside central visual field. It is very important to evaluate risks quantitatively.

  - Since it is a prototype, we have to keep checking the behaviors of this model. However this system can be applied to some new problems of road traffic.

Thank you very mach.