Using Artificial Intelligence Techniques in Computer Graphics

Dimitri PLEMENOS

MSI laboratory

Limoges - FRANCE

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What is the problem?

Some computer graphics problems are difficult to resolve using classical methods.

In this kind of situation, the use of Artificial Intelligence techniques can give more satisfactory solutions.

Main useful AI techniques for computer graphics

1. Problem resolution methods
   - Problem reduction
   - Heuristic search
   - Constraint satisfaction
2. Expert systems
3. Machine learning
   - Neural networks

Problem resolution methods

1. If there exists a formula giving the solution, apply this formula.
2. Enumerate all possibilities for a solution and evaluate each possibility to see if it is a solution.
3. If it is impossible to enumerate all possibilities for a solution, make a heuristic search in order to find partial interesting solutions.
4. If the problem is too complex to be resolved with one of the previous methods, decompose it in a set of sub-problems and apply to each of them one of the four problem resolution methods (problem reduction).

Heuristic search

1. Choose an action among the possible actions.
2. Apply the chosen action which modify the current state.
3. Evaluate the current state.
4. If the current state is a final state (close to a solution), stop the process. Otherwise, choose a new state and apply again the heuristic search process.

The choice of a new state can be made:

- By keeping the last obtained state.
- By backtracking and choice of the most promising action.

Constraint satisfaction

A Constraint Satisfaction Problem (CSP) is made of:

1. A set of variables.
2. A set of constraints on the values of variables.
3. A set of possible values of variables, called the domain of variables.

Example:

Variables: x, y, z.

Constraints: x=y+z, y<z.

Domains: x in [1..4], y in [1..5], z in [1..4]

Constraint satisfaction (continued)

Resolution of a constraint satisfaction problem consists to find, for each variable, a value verifying all the constraints of the CSP.

Example:

For the following CSP:

Variables: x, y, z.

Constraints: x=y+z, y<z.

Domains: x in [1..4], y in [1..5], z in [1..4]

A solution is: x=5, y=2, z=3.

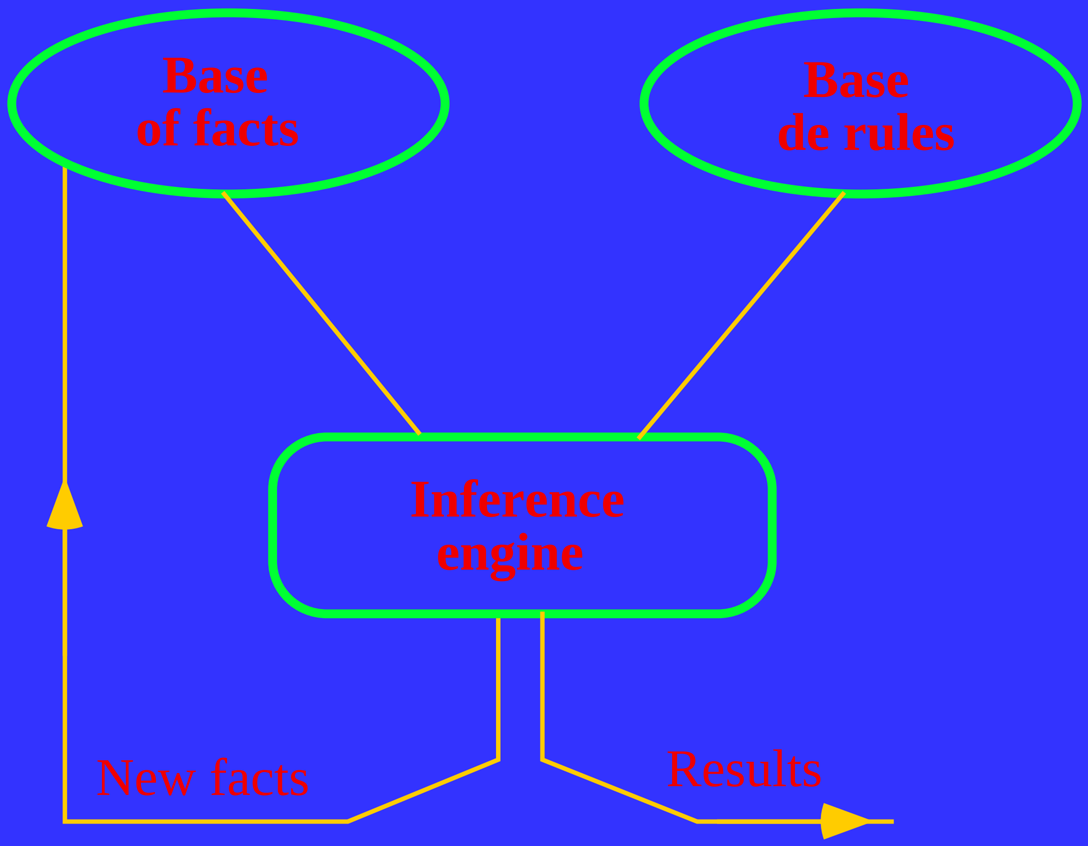
Constraint satisfaction (continued)

Resolution methods for a constraint satisfaction problem are composed of three phases:

1. Propagation, where restrictions on the domains of variables are propagated to all the variables of the CSP.
2. Test, where the system decides to stop the process (solution obtained or contradiction) or to reach the enumeration phase.
3. Enumeration, where a value is given to a variable, in order to reduce its domain, and the whole process is recursively applied to the new CSP.

Expert Systems

Architecture of an expert system



Machine learning

Men have always wanted to construct machines able to learn, because learning is the property that characterises better the human intelligence.

One of the most useful kinds of machine learning is learning by examples, where examples given by the teacher help the system to make generalisations and to deduce the good properties of objects.

After learning, the system can work as a filter accepting only objects with good properties.

Machine learning (continued)

Neural networks

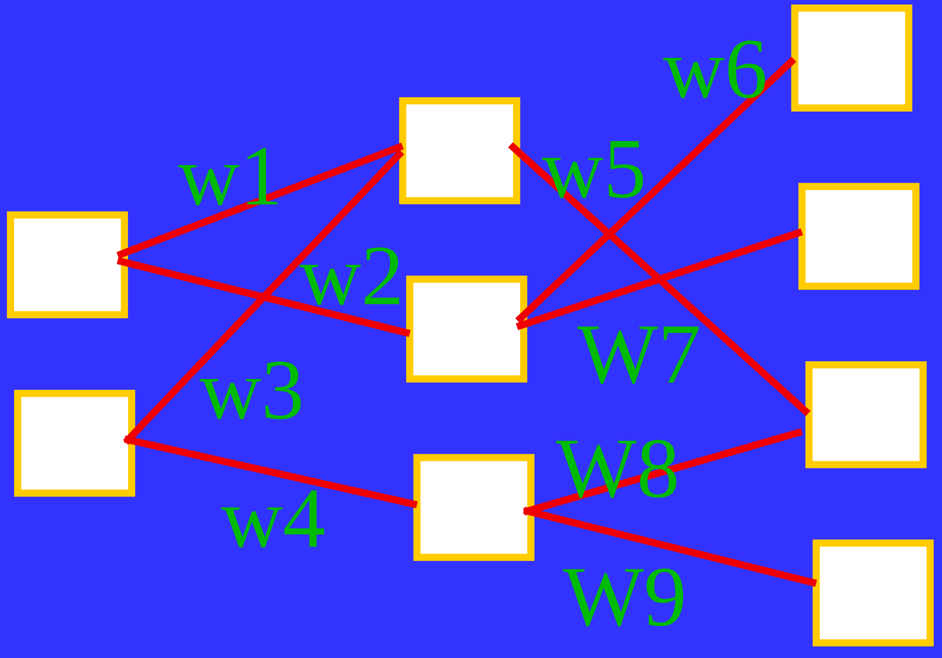
A neural network is a set of artificial neurones connected by links. A weight is associated to each link.

Each artificial neurone can transmit an information to its neighbours, only if the weights of the corresponding links are greater than a threshold value.

A learning rule is associated to each neural network. This rule defines the manner in which the weights of the network are modified, depending on examples presented to it.

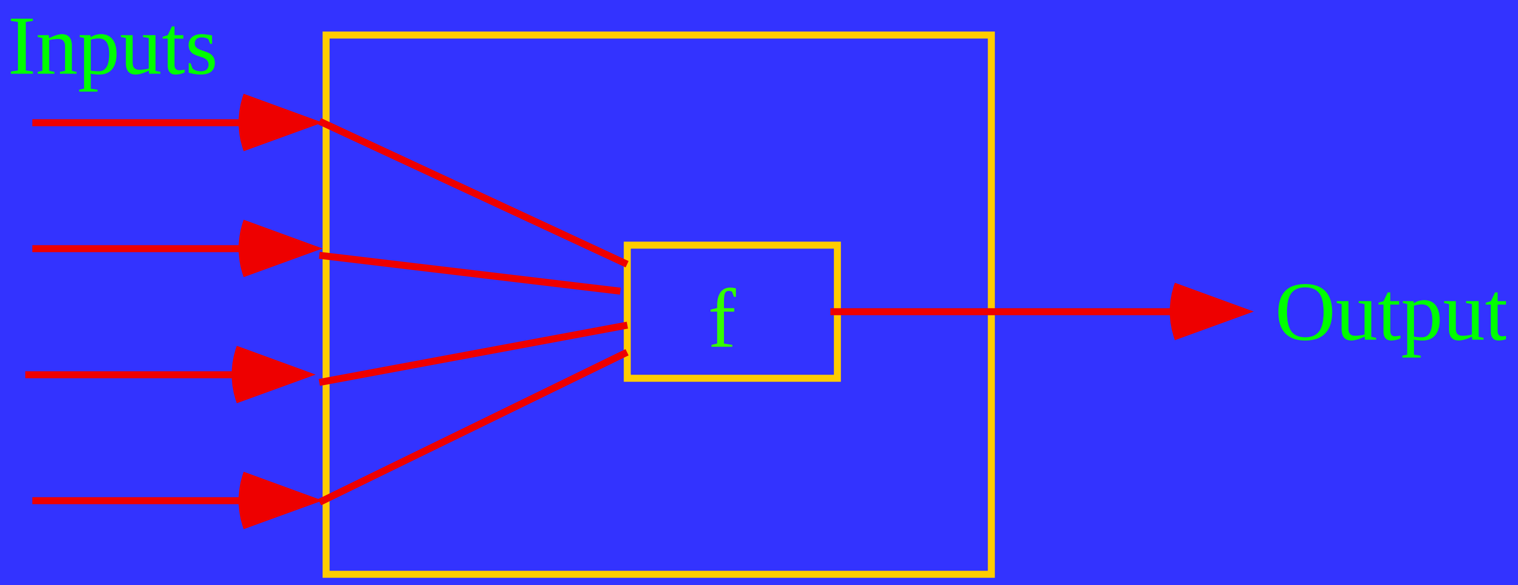
Machine learning (continued)

Neural network



Machine learning (continued)

Artificial neurone



f: activation function

Examples of computer graphics areas concerned by AI techniques

- Scene modelling
- Scene understanding
- Radiosity
- Etc.

Scene modelling

Main drawbacks of traditional scene modellers:

- The lack of abstraction levels in description
- The impossibility to use approximate or imprecise descriptions to express imprecise mental images of the designer.

The designer must have a very precise idea of the scene he (she) wants to create before using a modeller !

Scene modelling (continued)

An Artificial Intelligence based solution:

Declarative modelling

Declarative modelling allows the designer to get a scene by only declaring which properties have to be verified by the scene. The designer has not to indicate the manner to create the scene from its properties. Imprecise properties can be used to describe the scene.

Scene modelling (continued)

MultiFormes: a declarative scene modeller based on hierarchical decomposition.

Principle:

- a scene is easy to describe with a small number of properties: it is described.
- a scene is difficult to describe: it is decomposed into several sub-scenes and the hierarchical decomposition process is applied to each sub-scene.

Scene modelling (continued)

Artificial intelligence techniques used in MultiFormes:

1. Problem reduction by hierarchical decomposition.
2. Constraint satisfaction techniques. More precisely: CLP (FD) (Constraint Logic Programming on Finite Domain).

- Each property known by MultiFormes is described by a set of linear constraints.
- Each linear constraint is decomposed in a set of primitive constraints of the form “X in r” where X is a variable and r a range.

Scene modelling (continued)

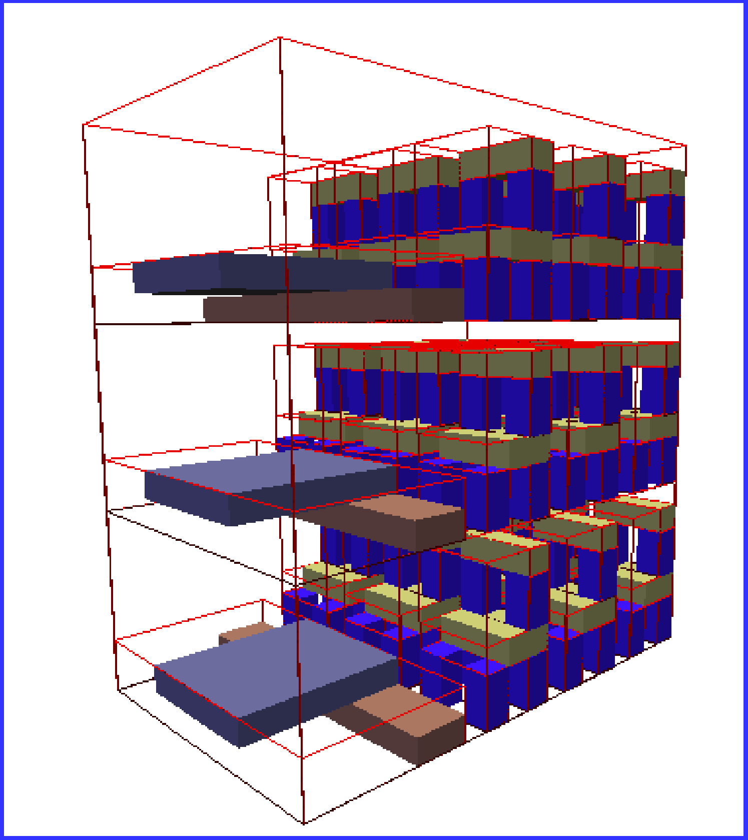
The resolution process in MultiFormes:

- The resolution process is applied to each primitive constraint, using heuristics permitting to process the variables in an order defined by the hierarchical decomposition tree.
- Constraint satisfaction techniques, together with heuristics exploiting hierarchical decomposition, ensure very efficient scene generation.

Scene modelling (continued)

Results with MultiFormes:

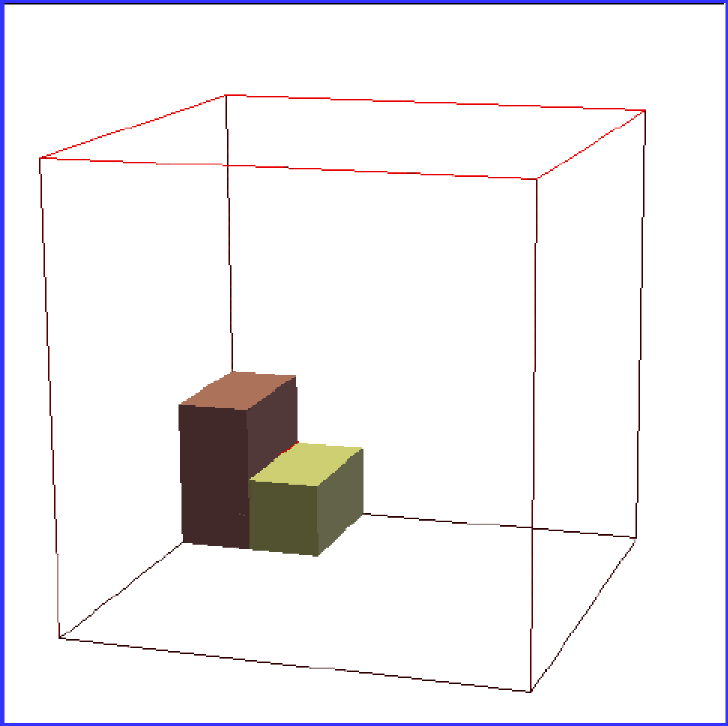
1. Three-floors building.



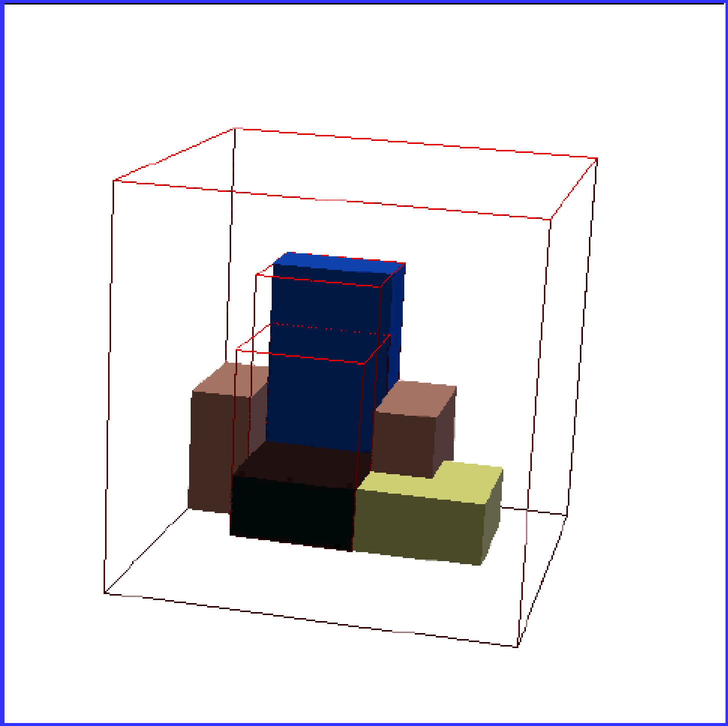
Scene modelling (continued)

Results with MultiFormes (continued):

2. Sofa.



Forward checking



Partial look-ahead

Scene Understanding

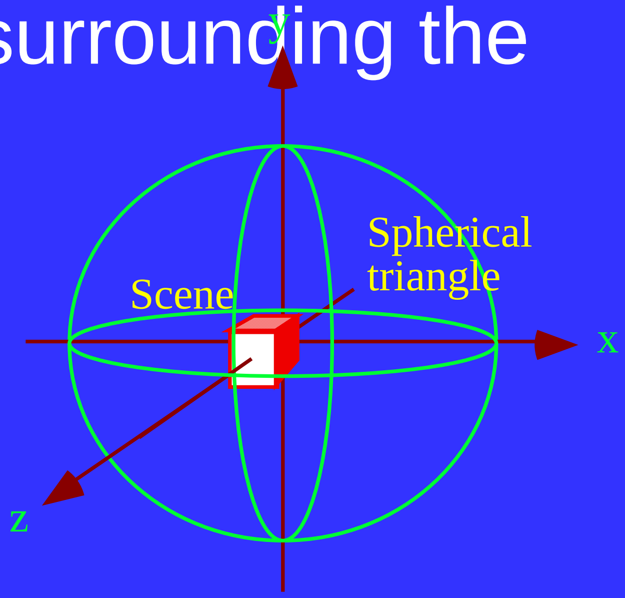
It is important to well understand a scene, designed with a modeller or found in the net. Two ways:

- Static understanding by automatic calculation of a good point of view.
- Dynamic understanding by simulating the movement of a virtual camera around the scene.

Scene Understanding (continued)

- Static understanding

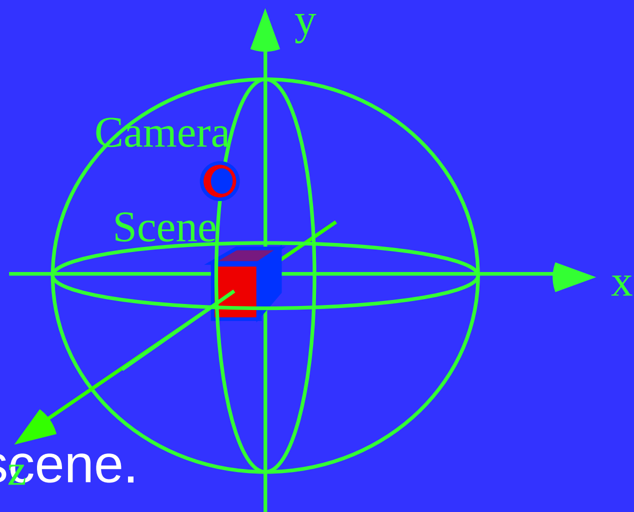
Computation of a good point of view on the surface of a sphere surrounding the scene.



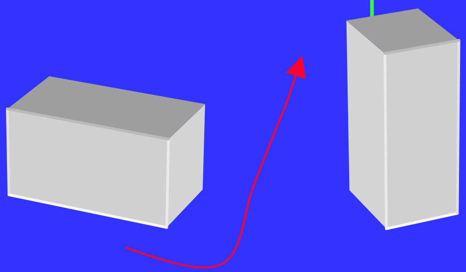
Artificial intelligence technique used: Heuristic search.

Scene Understanding (continued)

- Dynamic understanding
- The camera moves on the surface of a sphere surrounding the scene. In this technique, the camera remains in the exterior of the scene.

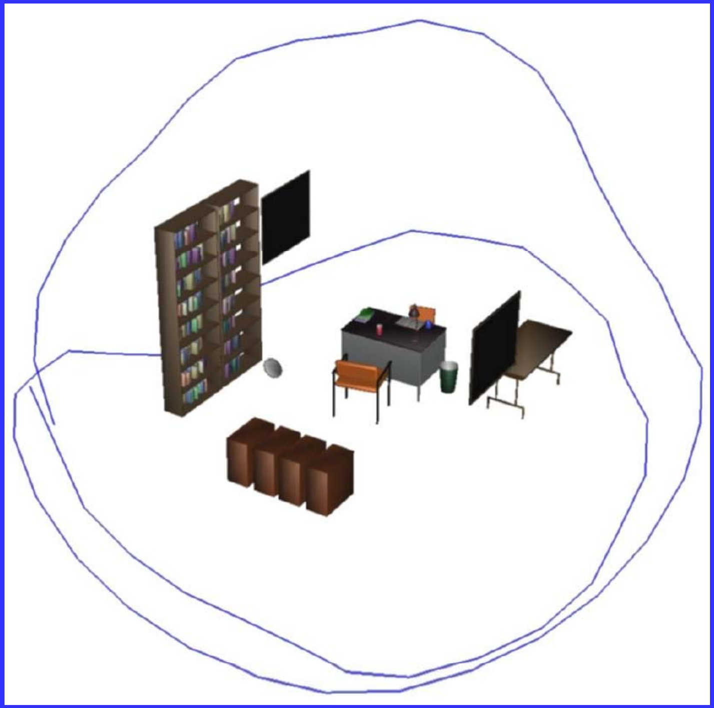


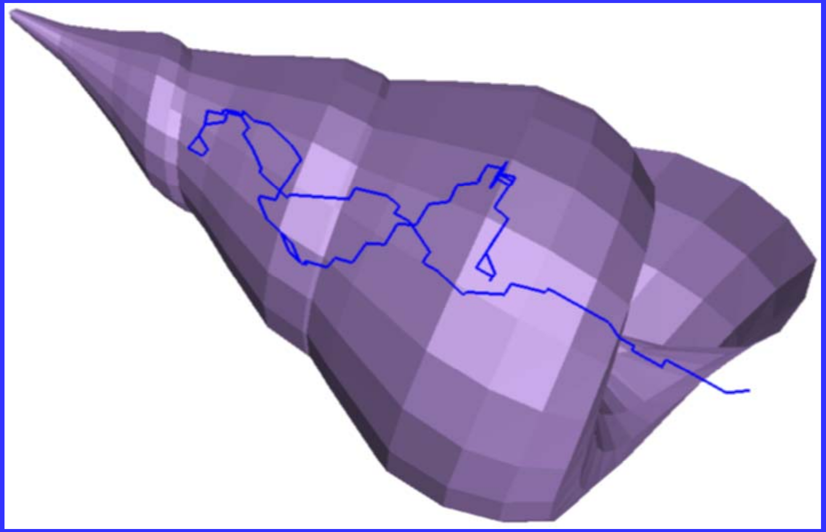
- The camera visits the interior of the scene.



Scene Understanding (continued)

- Dynamic understanding (continued)





Used AI techniques:

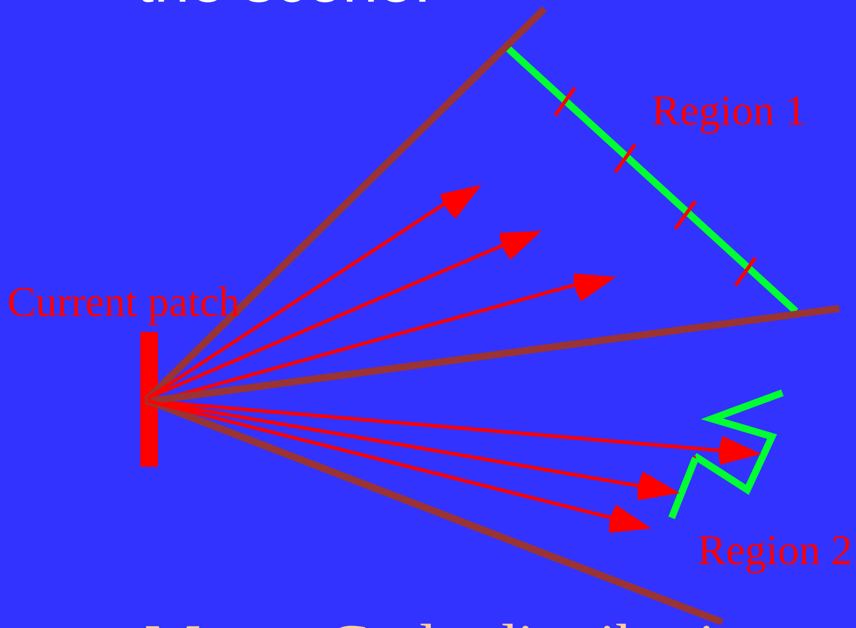
Heuristic multilevel search + other heuristics.

Scene Understanding (continued)

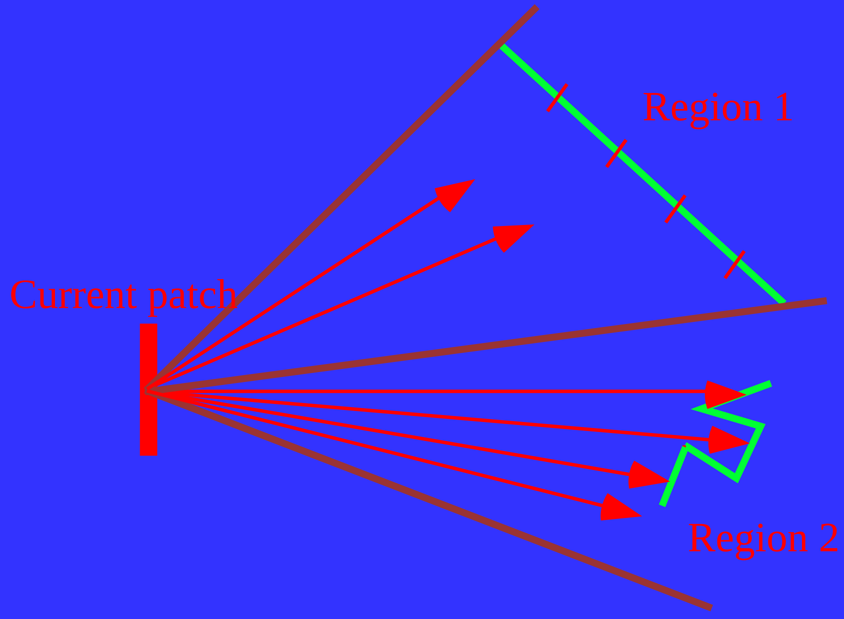
- Example of scene exploration

Scene Rendering - Radiosity

The problem with Monte Carlo based radiosity is that the sampling of the scene from a patch does not take into account the complexity of the different parts of the scene:



Monte Carlo distribution

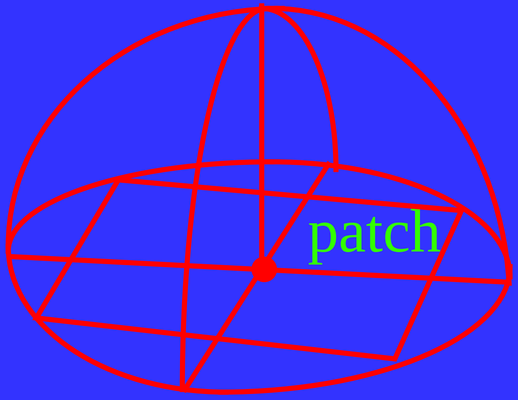


Expected distribution

Scene Rendering - Radiosity (continued)

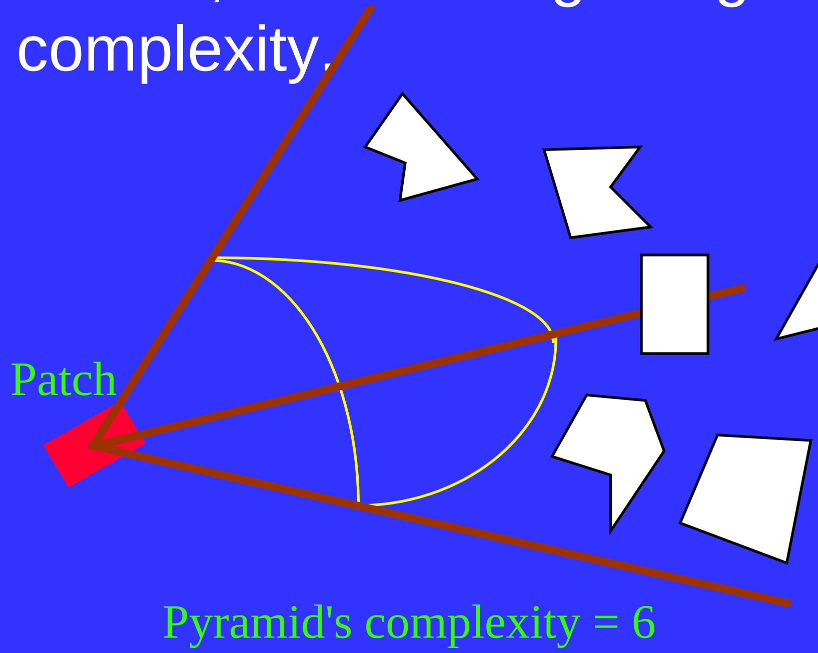
How to take into account the visual complexities of the different parts of a scene?

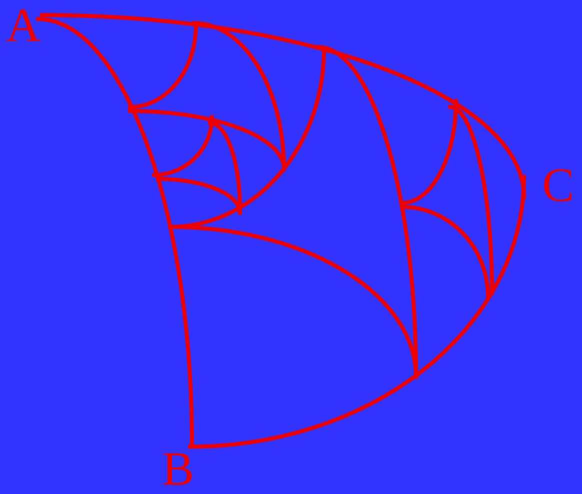
- The visual complexity of a region is approximated by the number of objects (patches) contained in the region.
- A region is defined as a triangular pyramid whose centre is the centre of the current patch and delimited by a spherical triangle on the surface of a hemisphere surrounding the patch.



Scene Rendering - Radiosity (continued)

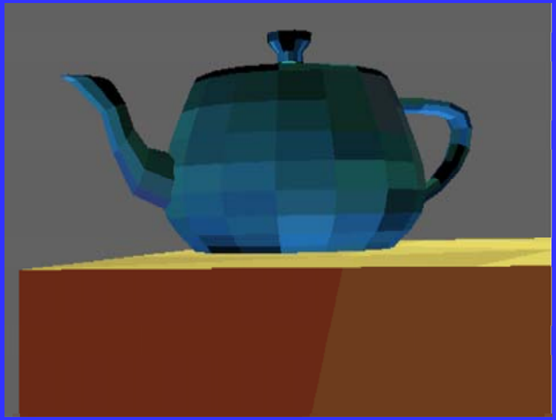
- Complex regions are subdivided, using heuristic search, in order to get regions with almost constant complexity.

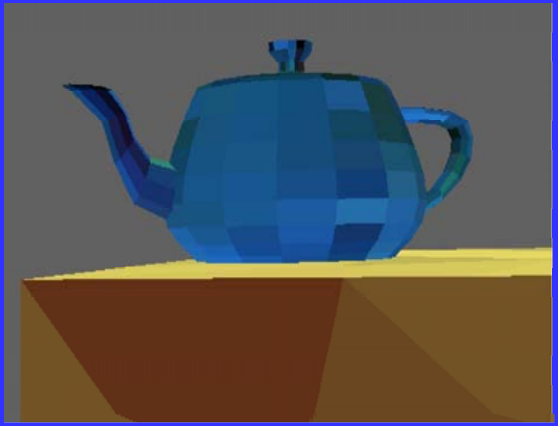




- The same number of rays is shot to each region of the scene to distribute the energy of the patch.

Scene Rendering - Radiosity (continued)





Traditional Monte Carlo Hemisphere subdivision

Conclusion

Some Artificial Intelligence techniques can be applied in various areas of computer graphics and improve the obtained results.

Techniques currently used :

- New constraint satisfaction techniques
- Heuristic search
- Strategy games techniques
- Machine learning

Conclusion (continued)

Other computer graphics areas could be improved with artificial intelligence techniques:

- Modelling of non geometric properties of a scene
- Automatic placement of light sources according to the expected results
- Designing test scenes with specific properties