Incremental Reconstruction based Bayesian learning

Zehuan Yuan

Advisor: Dr. Tong Lu

Dept. Of Computer Science and Technology

Nanjing University

June 9,2012

zhyuan001@gmail.com

Context

- Background
  - 3D Model
  - Insights into some problems
- Incremental reconstruction
  - Goal
  - PMVS
  - Model
  - Algorithm
- Experiments

3d model

- "Digital copy" of real object

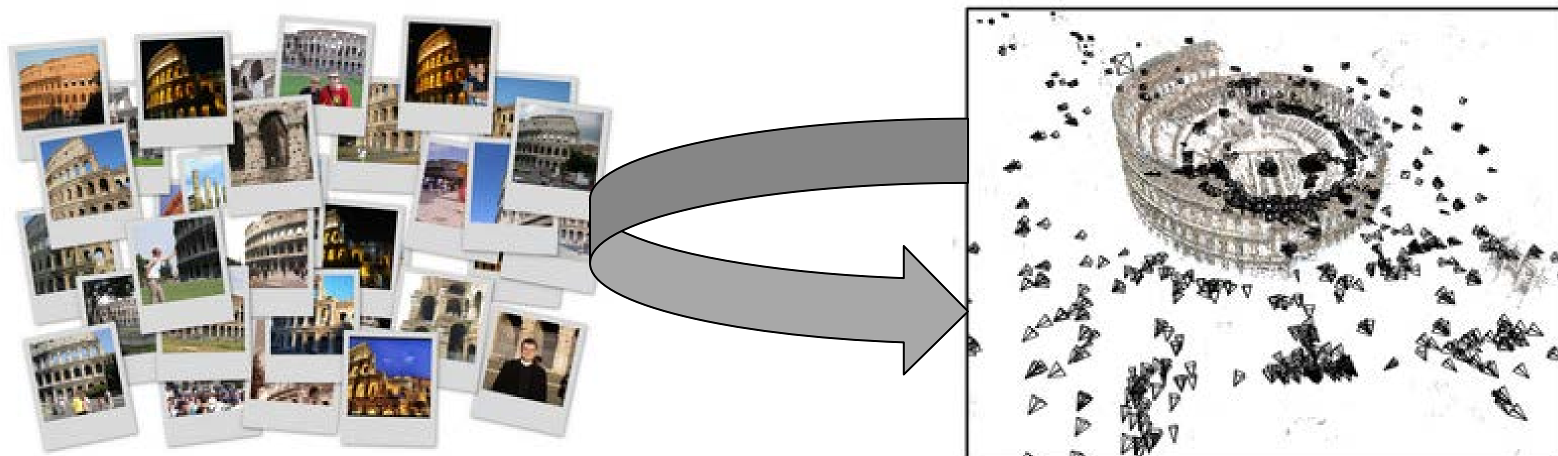
- Allows us to
  - Inspect details of object
  - Measure properties
  - Reproduce in different material

- Many applications
  - Cultural heritage preservation
  - Computer games and movies
  - City modelling
  - E-commerce
  - 3d object recognition/scene analysis

From Yasutaka Furukawa's tutorial in CVPR2010

3D Reconstruction

Building 3D object or scene from images and videos obtained in different views



Build Rome In a day

Problems

- Dataset
  - illumination， images from Internet, videos

- Applications
  - Real-time reconstruction
- Update of 3D model
  - Multi-resolution reconstruction

Incremental reconstruction

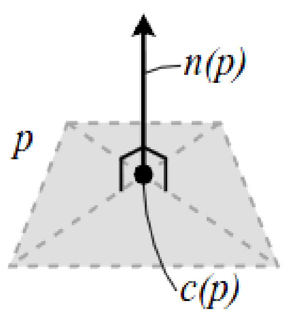
Incremental reconstruction

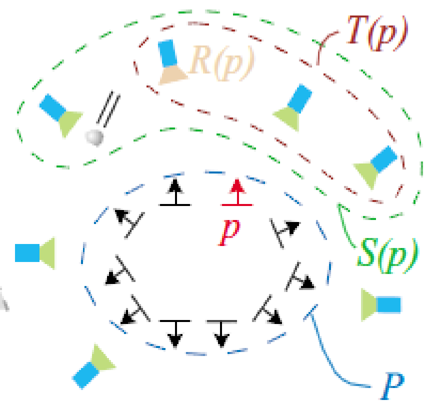
- Goal
  - Asynchronous input
  - Update of 3D model
- Incremental reconstruction
  - Exploiting the input images
  - Refine the model under geometric constraints

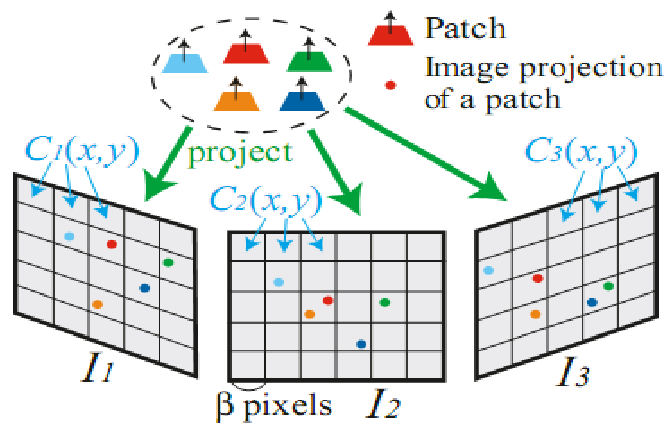
Bayesian Model

PMVS

- Patch-based multi-view stereopsis
  - A 3D representation Model
- *A patch p*
  - ✓ *c(p), n(p),V(p) ,R(p)*







From Yasutaka Furukawa and Jean Ponce's paper

Bayesian model

- Observation
  - An input image is a measurement of 3D model
  - The most likely surface is obtained by maximizing the posterior.
- Model

$$p(S \mid i_{new}) = \frac{1}{Z} p(i_{new} \mid S) p(S), S \in \Omega$$

$$S_{MAP} = \arg\min\ (-\log p(i_{new} \mid S) - \log p(S))$$

- Prior and likelihood function
  - $P(i_{new}|S)$——likelihood function，
  - $P(S)$——geometric prior

Likelihood function

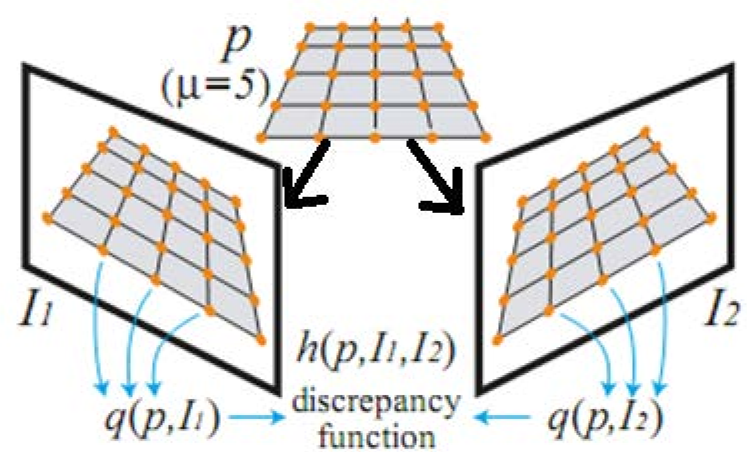
- Representation

$$p(i_{new} \mid S) \propto \exp(-\eta E_p)$$

- Photometric consistency
  - visual compatibility

$$E_p = \frac{1}{|S|}\sum_{p\in S}\frac{1}{|V(p)|-1}\sum_{i\in V(p)/i_{new}} h(p, i_{new}, i)$$

- Discrepancy function



Prior

- Representation

$$p(S) \propto \exp(-\{\lambda E_1 + \zeta E_2\})$$

- E_1

$$E_1 = \frac{1}{|S|}\sum_{p\in S}\frac{1}{|N(p)|}\sum_{v\in N(p)} f(p,v)$$

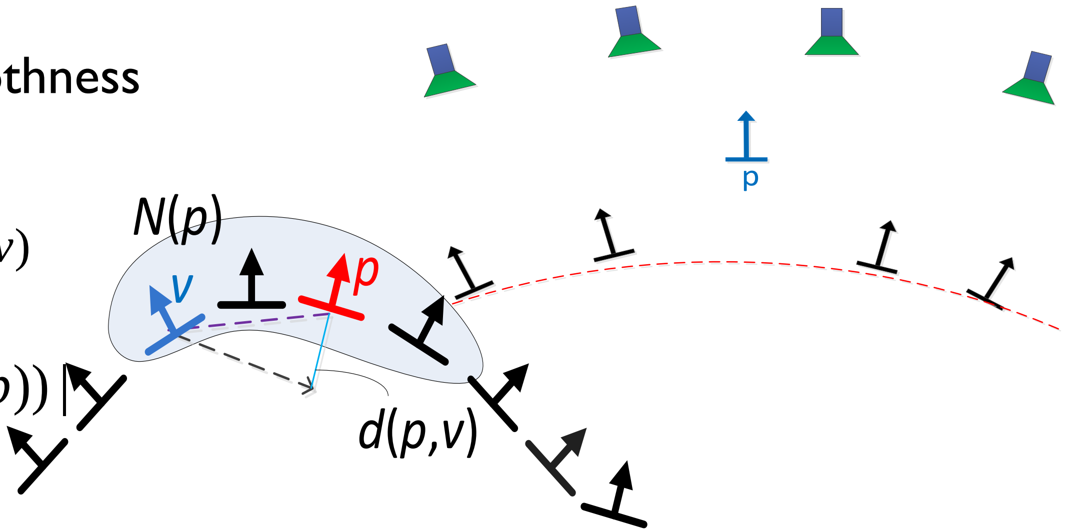
  - Function of curvature
  - Square-root prior

$$f(p,v) = \sqrt{(n(p)-n(v))^T(n(p)-n(v))}$$

- E_2
  - Enhance the smoothness

$$E_2 = \frac{1}{|S|}\sum_{p\in S}\frac{1}{|N(p)|}\sum_{v\in N(p)} d(p,v)$$

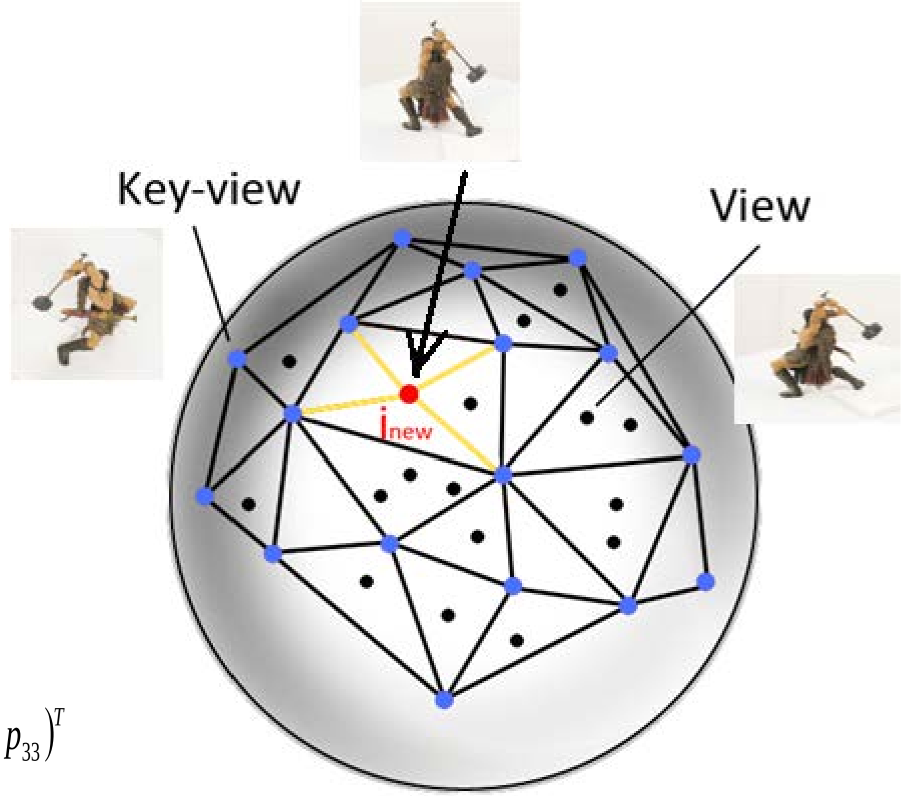
$$d(p,v) = |n(p)\cdot(c(v)-c(p))|$$



Algorithm

- *Step1:*Initialization
  - Goal
    - View sphere
    - 3D model
  - Process
    - Sample key views

$$P = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \end{bmatrix} \quad N = \begin{pmatrix} p_{31} & p_{32} & p_{33} \end{pmatrix}^T$$



View Sphere

    - Delaunay triangulation
    - 3D reconstruction from key views
      - PMVS(Patch-based multi-view stereopsis)

Algorithm

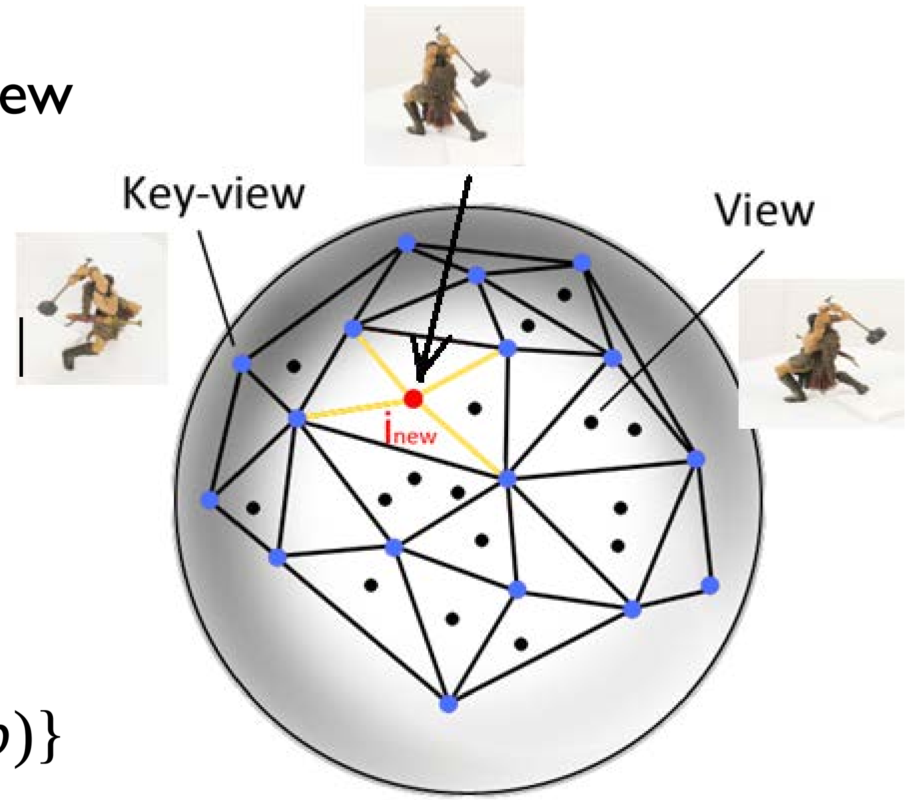
- *Step2:*Locate the new view
  - SIFT

$$T \leftarrow \arg\max_{T} \sum\nolimits_{v\in T} | x^{v}_{i_{new}} |$$

  - P_{update}
    - *A subset of patches*
    - *Reduce the dimensionality without loss of accuracy*

$$P_{update} = \bigcup_{v\in T} \{ p \mid v \text{ is } R(p) \}$$

- *Step3:*Update view sphere



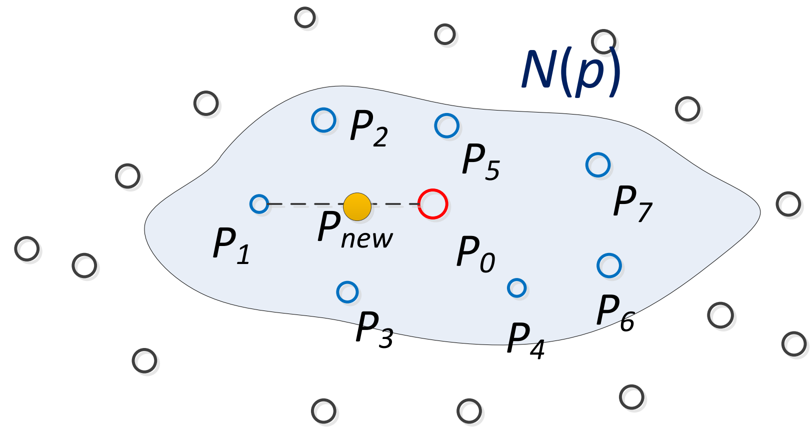
View Sphere

Algorithm

- *Step4:*Extension
  - Goal
    - Increase resolution
    - Make patches uniform
  - Method
    - Density

$$N(p) = \{p' \mid p' \in \overline{S}, |(c(p) - c(p')) \cdot n(p)| + |(c(p) - c(p')) \cdot n(p')| < \rho\}$$

$$D_p = |N(p)|$$



    - Procedure
      - SMOTE (Synthetic Minority Over-sampling Technique)

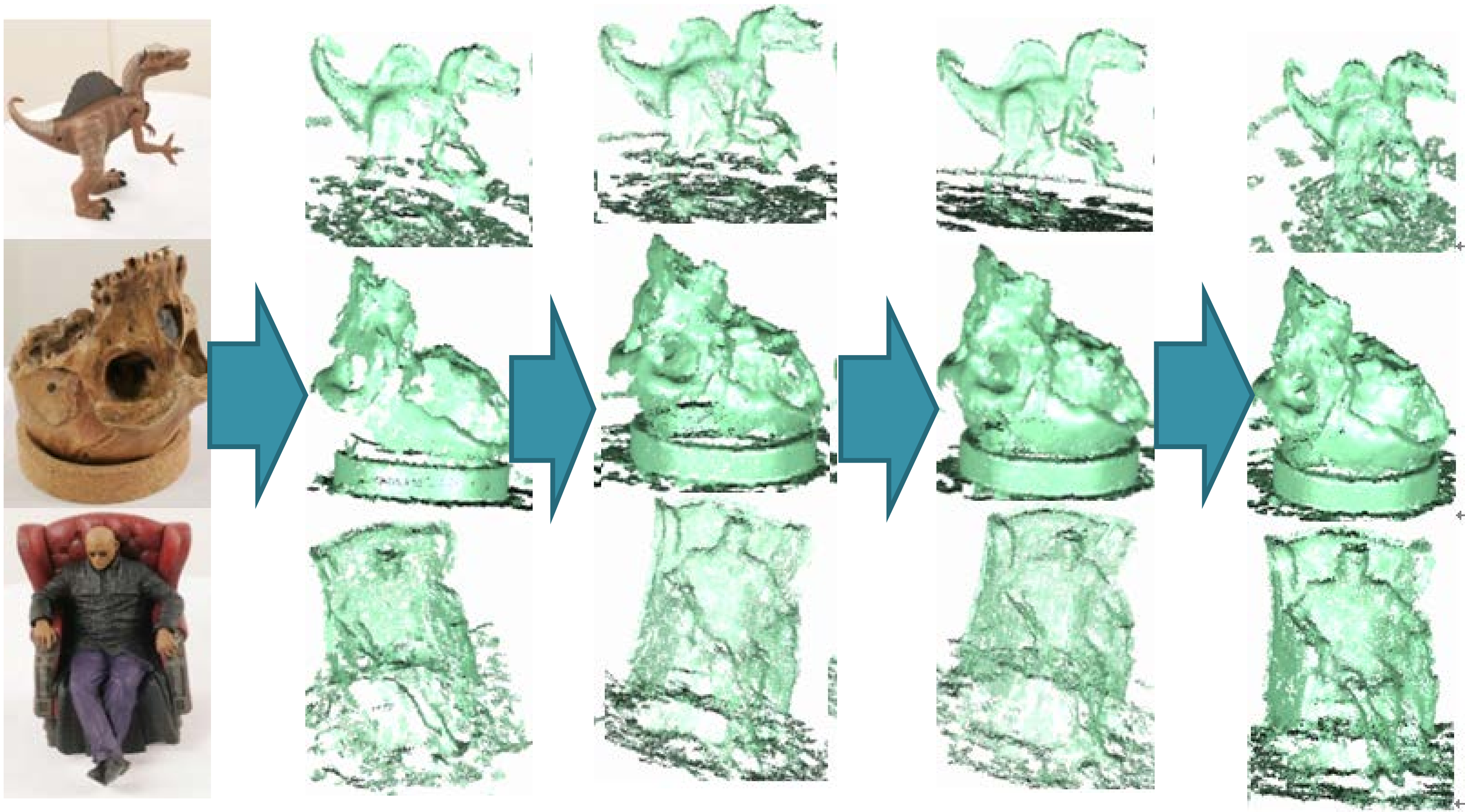
Algorithm

- *Step5:* Maximize the posterior
  - Global optimization

$$c(p), n(p) \leftarrow \arg\min(\lambda E_1 + \zeta E_2 + \eta E_p), p \in P_{update}$$

Experiment

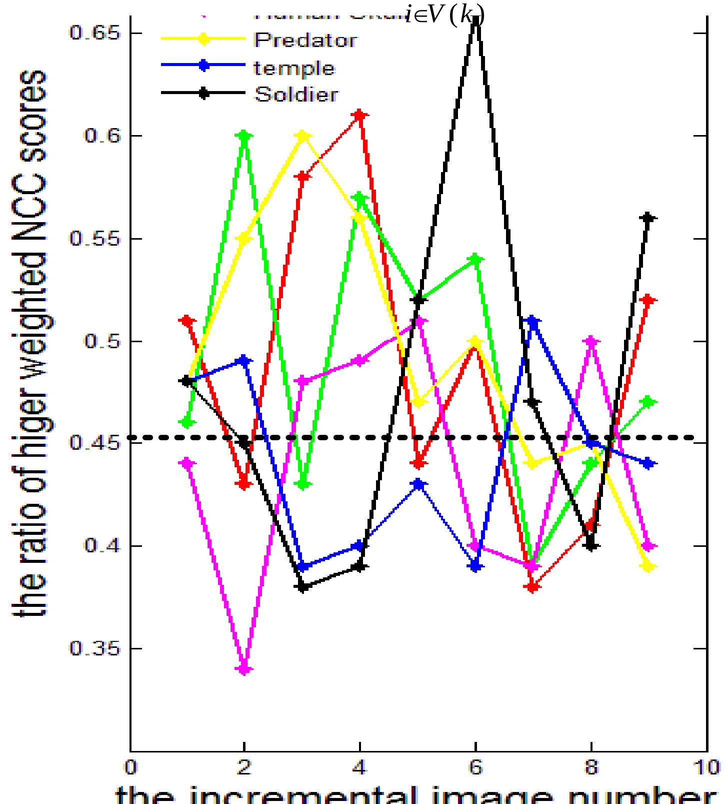
- Incremental reconstruction
  - Intuitive effects with new images input

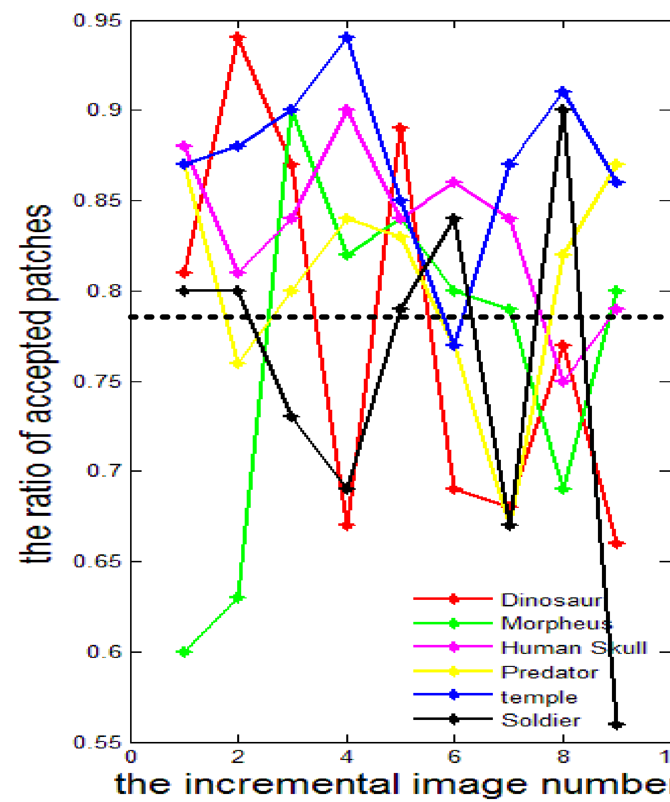


Experiment

- Statistical analysis
  - Measure of accuracy

$$P_k = \frac{1}{\sum_{i \in V(k)} r(k,i)} \sum_{i \in V(k)} \frac{h(k,R(k),i)}{r(k,i)}$$





Ends

ANY QUESTIONS?