Research @ Microsoft
Beijing, 2002 / 2003

Luiz Velho
IMPA

Part 1

The Place

2

The People

Microsoft®
微软亚洲研究院

Vision	*Graphics*	*NPR*	*Multimedia*
			
Shum, Harry	Guo, Baining	Xu, Ying-Qing	Zhang, Ya-Qin

Yunbo Cao Eric Chang George H-G Chen Lei-Eileen Chen Tong-Xian Chen Gang Chen Zheng Chen Liyong Chen Yu Chen Qi Chen Haitao Chen Yanyun Chen Kaijiang Chen Min Chu Stephen Dahl Yingnong Dang Jianfeng Gao Guangping Gao Xiaoming Gao Song Ge Xiaodong Gu Chuanxiong Guo Zhua Guo Hong Guo Baining Guo Lei He Chun-Hui Hu Yuxiao Hu Yazhua Hu Xian-Sheng Hua Chao Huang Ling Huang Jinxia Huang Chang-Ning Huang Shipeng Li Mingjing Li Jiang Li Stan Li Hang Li Bam-Wan Li Jianghong(Angela) Li Mu Li Cong Li Xun Li Yantao Li Lin Liang Hongbin Liao Shiding Lin Steve Lin Zhouchen Lin Bin Lin Zuoyang Liu Xiaobo Liu Ligang Liu Ce Liu Nien-Chen Liu Yunxin Liu Xinguo Liu Boying Lu Lie Lu Yufei Ma Wei-Ying Ma Xiaoxu Ma Chengyuan Ma Xin Ma Hu Peng Frank Seide Xiao-Li Sheila Shang Jacky Shen Yu Shi Heung-Yeung Shum Hong-Hui Sun Yan-Feng Sun Kun Tan Xin Tong Jian Wang Jin Wang Qing Wang Lifeng Wang Yijin Wang Lei Wang Xianfang Wang Qiang Wang Mingyu Wang Ji-Rong Wen Hua Wu Feng Wu Jiang Wu Zhe Xiang Rong Xiao Xing Xie Yongqiang Xiong Mingqing Xu Yihua Xu Ying-Qing Xu Hongyun Yang Yunxia Yang Binbin Yanhong Richard Yuqi Yao Qiufeng Yin Roger Yu Keman Yu Chun Yuan Huajun Zeng Yue Zhang Gao Zhang Bo Zhang Qian Zhang Ya-Qin Zhang Hong-Jiang Zhang Lei Zhang Yu Zhang Chunhui Zhang Zheng Zhang Ye Zhang Zhunping Zhang Benyu Zhang Yong Zhao Wei Zheng Ming Zhou Jian-Lai Zhou Kun Zhou Bin Zhu Wenwu Zhu Xinli Zou Yu Zou

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The Work

SIGGRAPH 2003
SAN DIEGO

PS: Not just SIGGRAPH papers…

4

Genealogy of a *SIGGRAPH Paper*

- Choose a *Hot / New* Topic
- *Know* the Area
- Go *Beyond* the State-of-the-Art
- Show *Convincing* (and Impressive) Results
- Make an *Perfect* Presentation

✶ Some *Luck* Helps!

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The Paper

SIGGRAPH 2003

Synthesis of Progressively-Variant Textures on Arbitrary Surfaces

Jingdan Zhang.	*Kun Zhou*	*Luiz Velho*	*Baining Guo*	*Harry Shum*
Tsinghua Univ.	MSR Asia	IMPA	MSR Asia	MSR Asia

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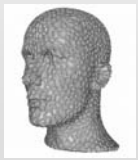
The State-of-the-Art

- Homogeneous Texture



- Synthesis on Surfaces

Beyond the State of the Art

- Natural Textures on Complex Objects


Texture Models

- Julesz Conjecture (*global statistics*)

  "Textures cannot be spontaneously discriminated if they have the same first-order and second-order statistics "

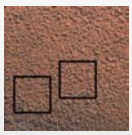
- Textons (*local features*)

  - local conspicuopus features

Two-Level Visual System
- *attentive system*: focal attention scanned serially.
- *pre-attentive system*: distributed attention mediated by parallel process

Homogeneous Textures

- Texture Model
  - Local
  - Stationary



✶ Second-Order Stationarity

Random Process: $\{X_s\}$

- $E(X_s) = \mu$ (constant)
- $Var(X_s) = \sigma^2$ (constant)
- $Cov(X_s, X_t) = C(r-s)$ (function of the distance)

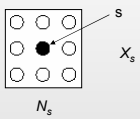
Probabilistic Model

- Markov Random Field
  - Lattice

    $S = \{ s = (i; j) : 0 \ i; j < M\}$

  - Neighborhood

    $N = \{ N_s \subset S, s \in S\}$



  - Local Conditional Probability Density Function

    $P(X_s = x_s) = P(x_s | x_r , r \in N_s\} ; x_s \in \Lambda_s$

Analysis Algorithm

- Non-Parametric MRF Model Estimation

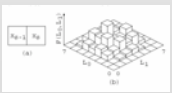
  Given a sample image $\mathbf{y} \in \Psi$ *and a* neighborhood system N, *build a* multidimensional histogram F

$$F(L_0, \ldots, L_N) = \sum_{\substack{p \in S_y \\ N_p \subset S_y}} \delta(y_p - L_0) \prod_{r \in N_p} \delta(y_r - L_{n_r})$$

  LPCDF estimation

$$\hat{P}(x_s | x_r, r \in N_s) = \frac{F(L_0 = x_s, L_{n_r} = x_r, r \in N_s)}{\sum_{L_0 \in \Lambda} F(L_0, L_{n_r} = x_r, r \in N_s)}$$

- 1D Example



Synthesis Algorithm

- Sampling from the *LPCDF*
  - *Impractical (Too Expensive, Huge Memory)*
- Neighborhood Search

Image X Surface Synthesis

Pixels/Vertices	grid	mesh re-tiling
Local Orientation (Vector field)	v, u	normal, tangent, bitangent
Synthesis Order	scanline	distance
Neighborhood		flattening/resampling

Quest for More General Textures

- Progressively-Variant Textures
  "characteristics change smoothly over domain"
- Locally-Stationary Random Fields
  - *Covariance is a smooth function over the domain*
    $Cov(X_s, X_r) = F(s, |r-s|)$, F *of class* C^k
  - ✶Recent Research
    (Mallat, Donoho, Dalhaus)
    - Local Cosine Best Basis
    → Spectral Estimation
  - *Need different approach for synthesis*

Contributions

Method for Generating PVT on Surfaces

- New Texture Model
  - Texton Based
- New CreationTools (2D)
  - User Control
- New Algorithm for Synthesis on Surfaces (3D)
  - Robustness

The Model

- $T_{P\text{-}V} = (S, M, F, V)$

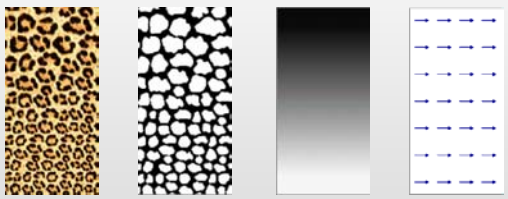


Image Sample | Texton Map | Transition Function | Orientation Field

How to Create the Model?

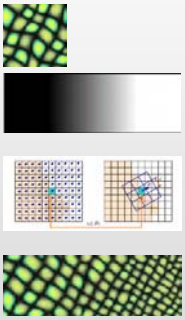
- Estimation Techniques (*Malik*)
  - Analysis from Samples
  - ✶ *Difficult Problem / Little Control*
- Image Processing Techniques
  - Transformation of Samples
  - 2D Manipulation Tools
  - Interactive
  - ✶*Good User Control*
  (*our proposal*)

Building the Model

- Tools
  - Field-Guided Distortion
  - Mask Extraction
  - Feature-Based Warping
  - Adapted Similarity Editing
  - Texton-Based Blending

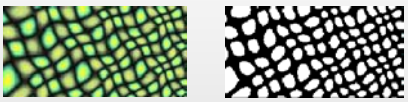
Distortion

- Input:
  - Homogeneous Sample
  - *Transition Function **
  - *Orientation Field **
- Processing
  - 2D Synthesis
- Output
  - Image Sample

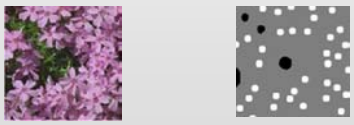


Segmentation

- Color Thresholding

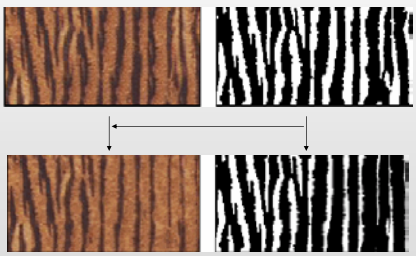


- Hand Painted



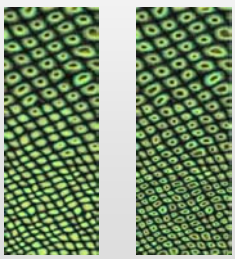
Warping

- Feature Based (*Texton Filtering*)



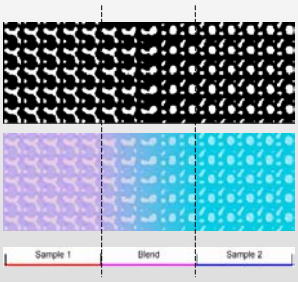
Editing

- Weighted Similarity
  (*extend Brooks*)
  - Transition Function
- Operations
  - Painting
  - Warping
  - Morphological



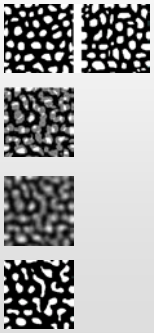
Blending

1. Generate Transition Texton Map
2. Synthesize Image Sample



Texton Map Blending

1. Interpolate Maps in 3D
2. Take Diagonal Slice
3. Gaussian Blur
4. Threshold



Example

- Crafting a Leopard Skin

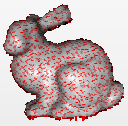
Synthesis

- Problem:
  - Matching
    Transition / Orientation
- Challenge
  - Texture Breaking

✶*Our Solution*:
- New Metric

Overview

- Input
  - 2D Texture Model
    $T_{P\text{-}V} = (S, M, F, V)$
  - Triangulated Surface
    - Mesh
  - Transition / Orientation Fields on Surface
    - User-Specified
- Output
  - Texture Maps
  - Texture Coordinate Assignement

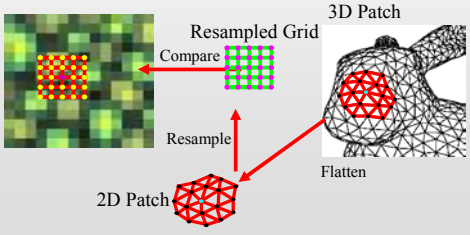


Single Resolution / One Pass Algorithm

```
For each vertex v on surface
    construct neighborhoods N_c(v) and N_m(v)                          → 1
    build candidate pool C(v,ε)
    smallest_match = INFTY
    For each pixel p = (a,b) in C(v,ε)                                 → 2
        construct neighborhoods N_m(p)
        new_match = dist(N_m(v),N_m(p))
        If (new_match < smallest_match)                                → 3
            smallest_match = new_match
            mask_value = M_o(p)
    M_s(v) = mask_value
    smallest_match = INFTY
    For each pixel p = (a,b) in C(v,ε)
        construct neighborhoods N_c(p) and N_m(p)
        new_match = dist(N_c(v),N_c(p)) + dist(N_m(v),N_m(p))          → 4
        If (new_match < smallest_match)
            smallest_match = new_match
            color = T_o(p)
    T_s(v) = color
```


Mesh Neighborhoods

- $N_c(s, p)$, $N_m(s, p)$,
  - Orientation Alignment, $o = F(p)$
  - Scale Adjustment, $s = V(p)$
  - Resampling



Progressively-Variant Synthesis

- Candidate Pool

$C(v, \varepsilon)$ (i.e. *sample neighborhoods*)

- Match Transition Functions

$$|F_o(p) - F_s(v)| < \varepsilon$$

✶ *Needs Special Acceleration*

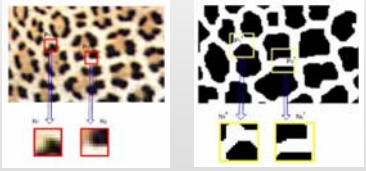
Acceleration

- K-Coherence

Metric

- Perceptual-Based (Texton)
  - damage resistant (*small histogram*)

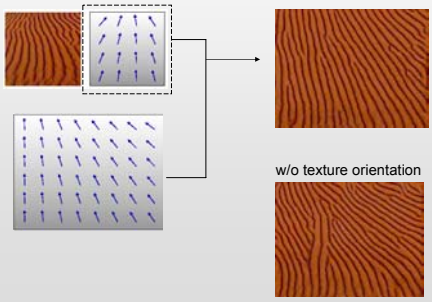
$$dist(N_c(v), N_c(p)) + dist(N_m(v), N_m(p))$$



- *Obs: 2-pass match*

Local Orientation Control

- Orientation on Mesh and Texture



Summary

- Video

Results

- Warping
  - Giraffe
  - Tiger
  - Horse
- Blending
  - Venus
  - Bunny

Giraffe

Tiger

Horse

Venus

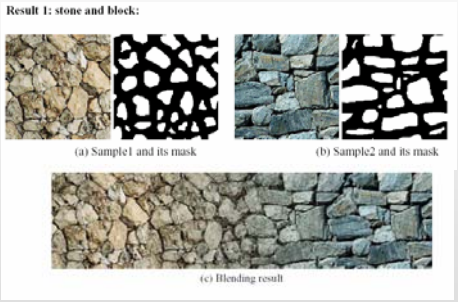
Bunny

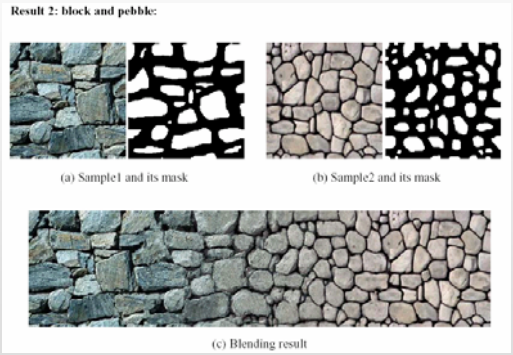
Timings

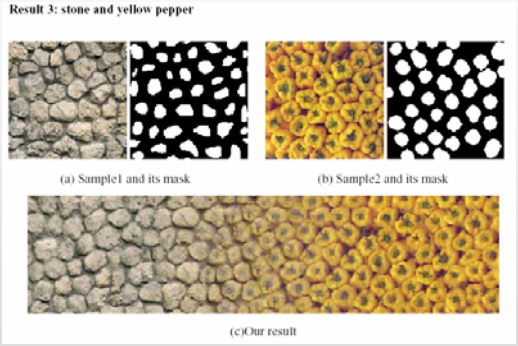
Mesh	Sample size	Vertex number	Time (minutes)
Venus	512×128	192k	44
Bunny	512×128	300k	104
Giraffe	384×96	106k	33
Tiger	256×64	170k	51
Horse	448×128	250k	39

Table 1: The timings are measured on a 2.4 GHz Xeon workstation.

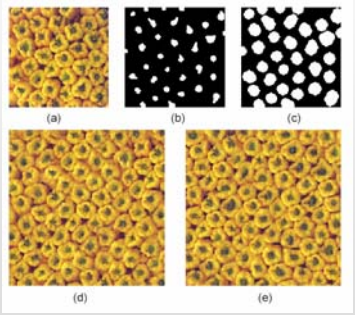
More Results

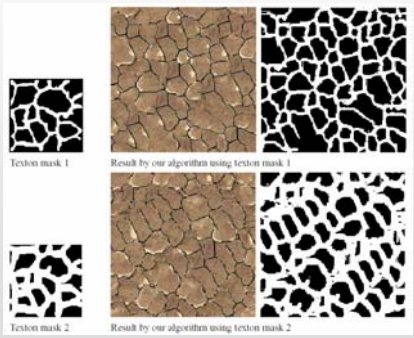






Effect of Different Texton Maps

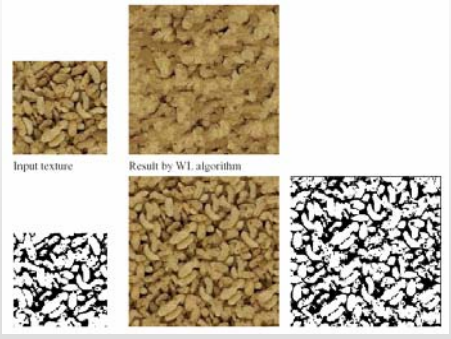


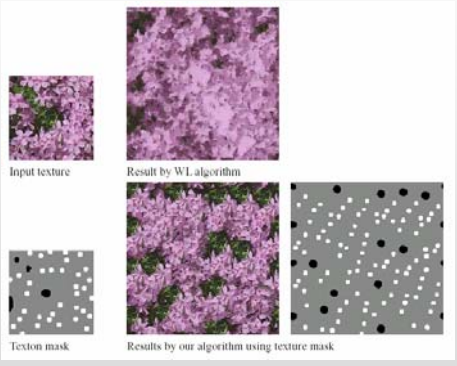


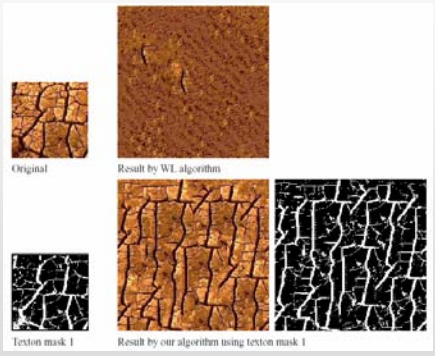
Comparisons

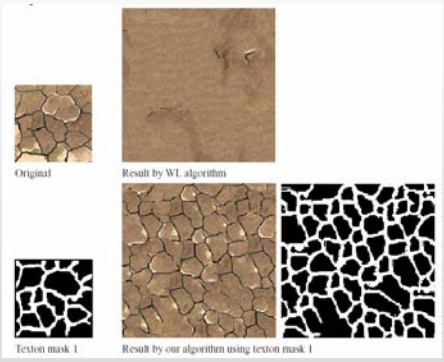
- Wei – Levoy Algorithm
- 2D Synthesis

✶ *Texton Map helps to deal with difficult textures*

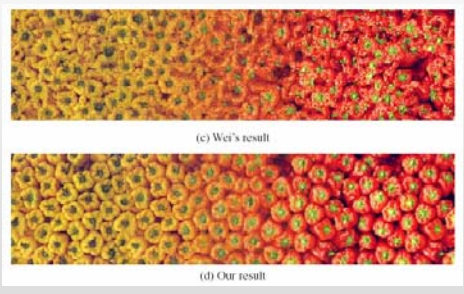




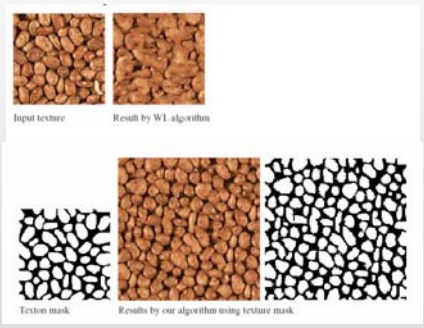




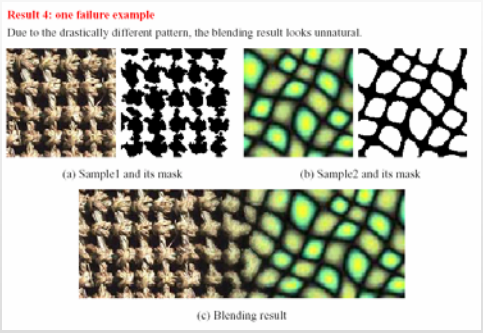
Blending Comparison



Synthesis Failure



Blending Failure



Future Work

- More Control of Feature-Based Blending
- Multi-Way Transition
- Other Ways to Control Texture Variation
- Synthesis of BTFs
- Micro-Geometry Synthesis

To be continued …