Master Computer Vision & Artificial Intelligence

# Real-Time Hand Pose Recognition using Depth Sensors combined with Spherical Shape Model Descriptor

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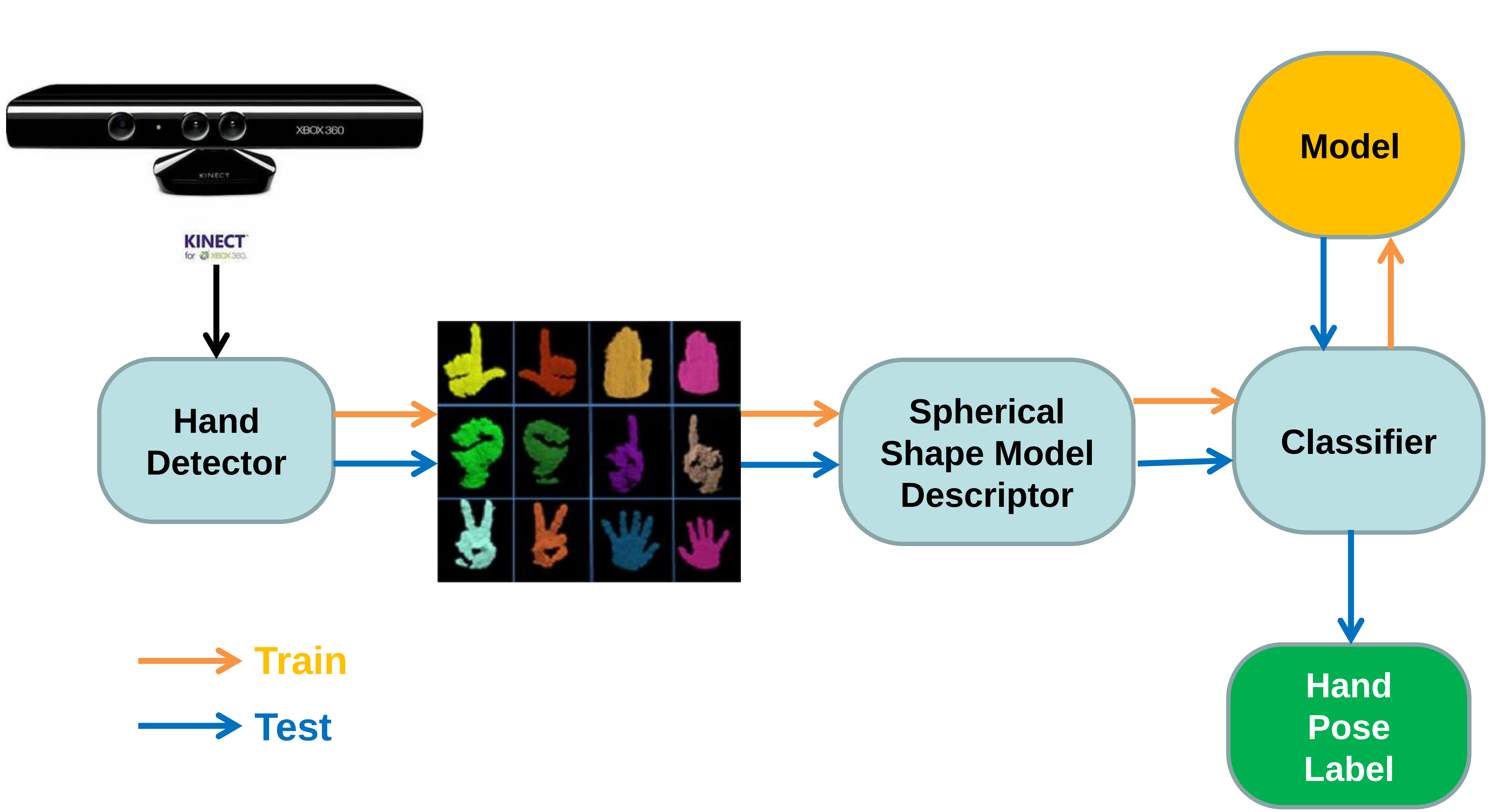
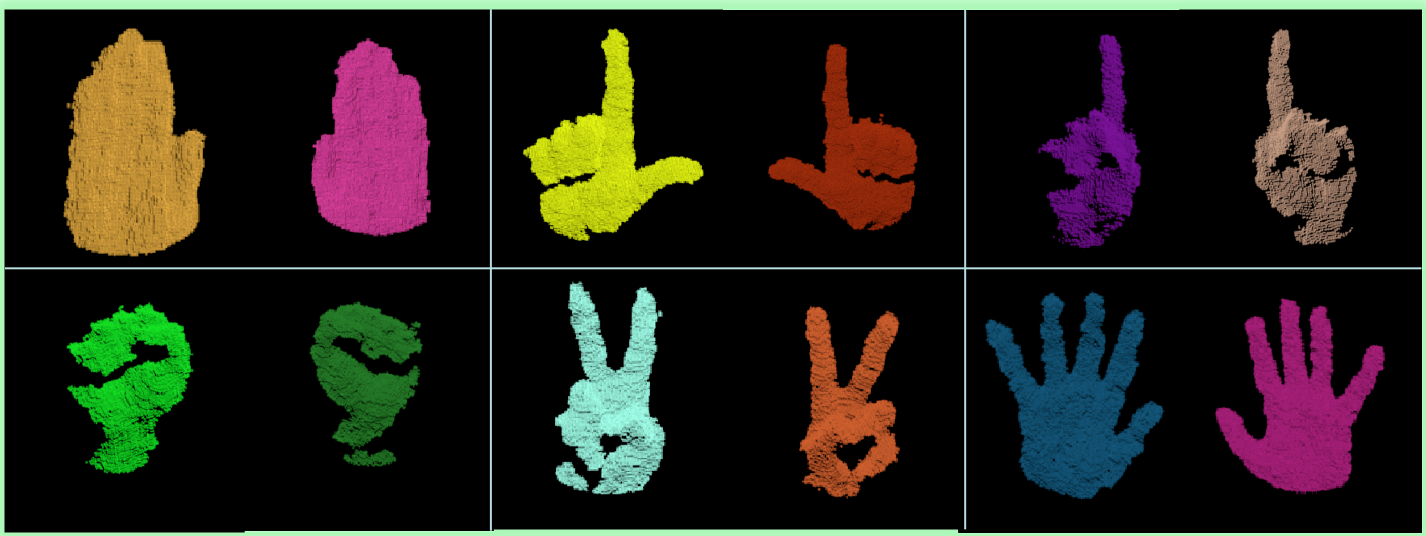
overview: g-speak
o b l o n g   i n d u s t r i e s

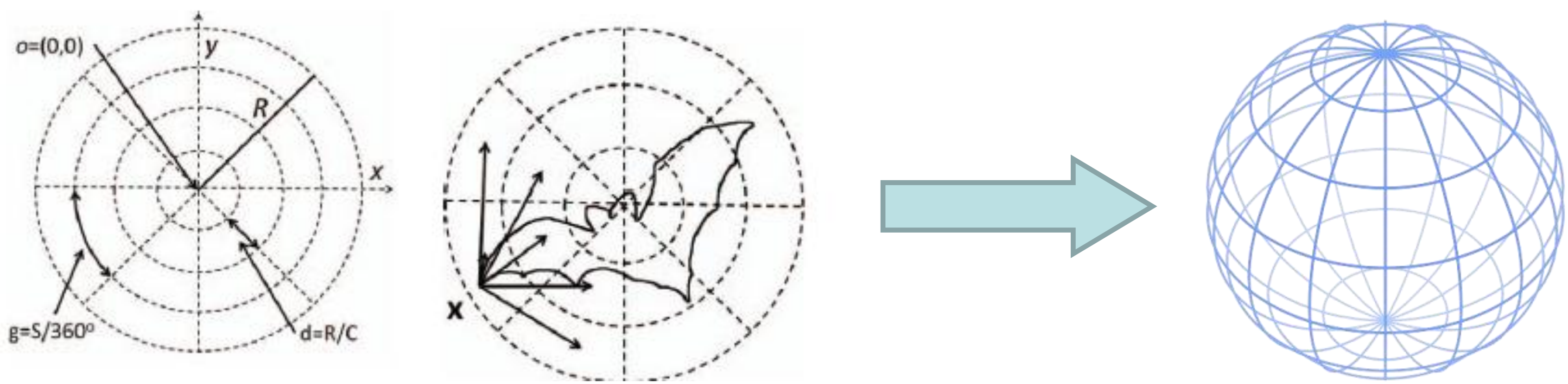

XBOX 360
KINECT
Hand Detector
Spherical Shape Model Descriptor
Classifier
Model
Hand Pose Label
Train
Test

- First the closest point is searched
  - Perform **a radius search** of 10cm, until the depth starts to rapidly increase.
  - If less **than 100 points** are obtained, then the sample is discard.
- Repeat the same procedure to find the second hand: the distance to camera must be within 30 cm of the first hand's closest distance and must more than 20 cm from the center of the first hand.

- No hand pose dataset is publicly available.
- New point cloud hand pose dataset must be creatred!
- The dataset was created using and adaptation of the hand detector.
- Includes **6 classes** with **2000 samples** (1000 per hand):
  - Each class includes both hands.
  - High hand orientation variability.
- Plus a *No-Pose* class.



- Current state-of-art point cloud descriptors (e.g PFH) have great computation overhead: ***$O(N^2)$***.
- The design of a novel descriptor is necessary!
- Circular Blurred Shape Model Descriptor [Escalera et al]
  - Very good discriminative power
  - Low computational requirements



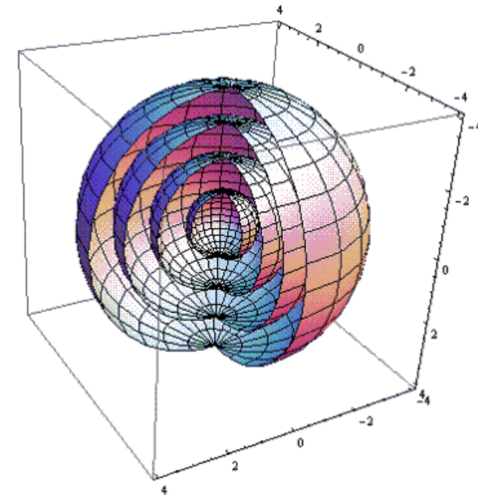

S. Escalera, A. Fornes, O. Pujol, A. Escudero, and P. Radeva, "Circular blurred shape model for symbol spotting in documents," in *Image Processing (ICIP), 2009 16th IEEE International Conference on*, nov. 2009, pp. 2005 –2008.

- Novel *Spherical Blurred Shape Model* Descriptor (SBSM)

$$P = \{p_i \mid p_i \in \mathbb{R}^3\}$$

$N_L$ number radial layers
$N_\theta$ number of $\theta$ angular divisions
$N_\phi$ number of $\phi$ angular divisions
$S_{Radius}$ sphere radius

$$S_R = S_{Radius}/N_L$$
$$S_\theta = 2\pi/N_\theta$$
$$S_\phi = 2\pi/N_\phi$$

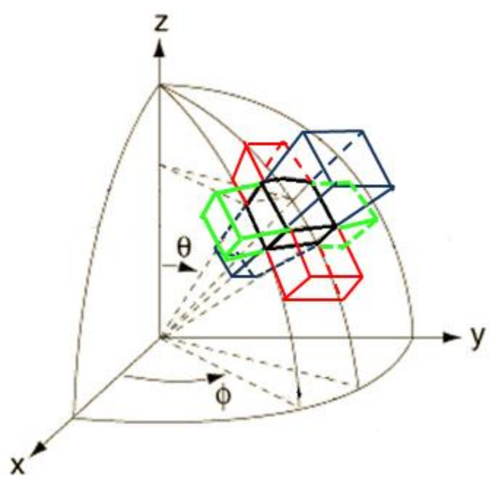


$B$ the ordered set of bins for the spherical description of $P^*$

$b^*_{\{i,j,k\}}$ the centroid of the section $b_{\{i,j,k\}} \in B$.

$$W_n = 0, n \in \{1, \ldots, N_L N_\phi N_\phi\}$$

foreach $p_n \in P^*$ do
  $b_x : b_x \in B, p_n \subset b_x$
  $W(b_x) = 1$
  foreach $b_{i,j,k} \in N(b_x)$ do
    $d_{i,j,k} = d(b_{i,j,k}, p_n) = ||p_n - b^*_x||$
    $W(b_{i,j,k}) = W(b_{i,j,k}) + \frac{1}{d_{i,j,k}}$
  end
end

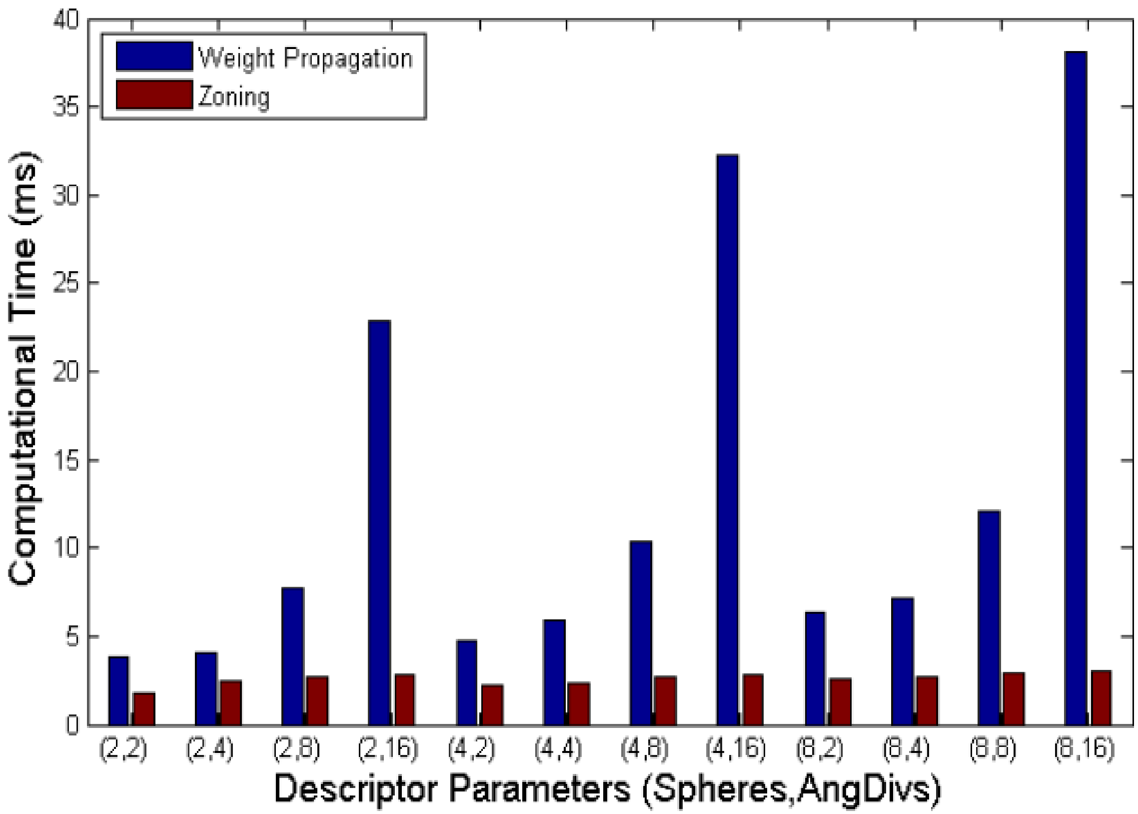



Normalize the vector $W$

$$\frac{W_i}{\#P}, i \in \{1, \ldots, N_L N_\phi N_\phi\}$$

- Test settings:
  - Descriptor testing considered $\begin{cases} N_L = \{2,4,8\} \\ N_\theta = N\phi = \{2,4,8,16\} \end{cases}$
  - The classification was performed as multiclass one-versus-one, using the libSVM framework.
  - Each combination pair was executed 10 times for cross-validation test.
    - Each execution considered 70% train data of each dataset class samples (randomly picked).
    - Every test run comprises a cross-validation of the train data for fine tune C-SVM (RBF Kernel) parameters: C and $\gamma$ .
  - Previous settings were considered in two descriptor modalities:
    - Weight Propagation.
    - Zoning.

| Descriptor Configuration | | | Average Accuracy | |
|---|---|---|---|---|
| Layers | Angles | Features | Weight Propagation | Zoning |
| 2 | 2 | 9 | 78.425 | **89.278** |
| 2 | 4 | 33 | **94.027** | 90.797 |
| 2 | 8 | 129 | 98.046 | **98.709** |
| 2 | 16 | 513 | 98.680 | **99.498** |
| 4 | 2 | 17 | **98.599** | 96.941 |
| 4 | 4 | 65 | 98.637 | **99.539** |
| 4 | 8 | 257 | **99.847** | 99.479 |
| 4 | 16 | 1025 | **99.818** | 99.796 |
| 8 | 2 | 33 | **99.657** | 99.627 |
| 8 | 4 | 129 | **99.772** | 99.713 |
| 8 | 8 | 513 | **99.839** | 99.527 |
| 8 | 16 | 2049 | **99.785** | 99.598 |


Weight Propagation
Zoning
Computational Time (ms)
0
5
10
15
20
25
30
35
40
(2,2)
(2,4)
(2,8)
(2,16)
(4,2)
(4,4)
(4,8)
(4,16)
(8,2)
(8,4)
(8,8)
(8,16)
Descriptor Parameters (Spheres,AngDivs)


KINECT

OpenNI

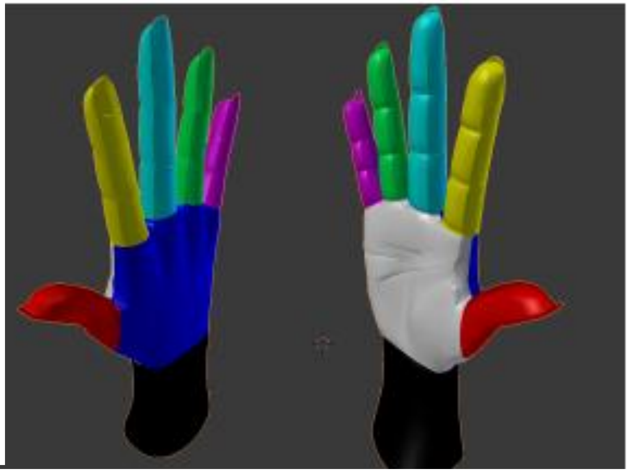
pointcloudlibrary

Eigen

| | |
|---|---|
| Processor: | Intel(R) Core(TM) i5-2430M CPU @ 2.40GHz |
| Installed memory (RAM): | 4.00 GB |
| System type: | 64-bit Operating System |

- The proposed system achieves the proposed design goal of a real-time hand pose recognition, with an end-to-end performance of 14fps.
- The SBSM descriptor is crucial for the results obtained:
  - High discriminative power for hand pose point cloud.
  - Small computational overhead.
  - Slight advantage of blurring aspect versus Zoning, encourage further studies.

- As future work…
  - Creation of a more difficult **multi-user dataset**.
  - Implement the descriptor algorithm using the **GPU** (Grapics processing unit) for a performance boost.
  - Include a pre-description phase, for a per-pixel classification using **Random Forest** classifier, in order to perform **Label Blurring**, to increase the robustness of the overall pipeline.



# Thank You!

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