Learning to Look at Humans

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Status Meeting SPP 1183 “Organic Computing“

Book Status

- All contributions are in.
- Index is ready.
- Introduction is at 70%.
- Distributed to authors by 28 September.
- Available at your bookstore around January 2008.

Contents

ACM TAAS Special Section Status

- 8 submissions
- 4 editors
- About 10 reviews are in.
- Some reviewing by TAAS editor to be done.

Publications

Publications

[1] Rolf P. Würtz. Organic Computing methods for face recognition. *it – Information Technology*, 47(4):207–211, 2005.

[2] Maximilian Krüger, Christoph von der Malsburg, and Rolf P. Würtz. Self-organized evaluation of dynamic hand gestures for sign language recognition. In Würtz [3]. Submitted.

[3] Rolf P. Würtz, editor. *Organic Computing*. Springer, 2007. In preparation.

[4] Rolf P. Würtz. Organic computing for video analysis. In Andreas König and Mario Köppen, editors, *Proceedings of 7th International Conference on Hybrid Intelligent Systems, Kaiserslautern, Germany*. IEEE Computer Society Press, 2007. In press.

[5] K. Bellman, P. Hofmann, Ch. Müller-Schloer, H. Schmeck, and R.P. Würtz, editors. *Organic Computing – Controlled Emergence*, number 06031 in Dagstuhl Seminar Proceedings. Internationales Begegnungs- und Forschungszentrum (IBFI), Schloss Dagstuhl, Germany, 2006.

[6] Alexander Heinrichs, Marco K. Müller, Andreas H.J. Tewes, and Rolf P. Würtz. Graphs with principal components of Gabor wavelet features for improved face recognition. In Gabriel Cristóbal, Bahram Javidi, and Santiago Vallmitjana, editors, *Information Optics: 5th International Workshop on Information Optics; WIO'06*, pages 243–252. American Institute of Physics, 2006.

[7] Witali Kusnezow, Wilfried Horn, and Rolf P. Würtz. A linear PDE-based approach for edge-tolerant image smoothing and object discrimination. *Electronic Letters on Computer Vision and Image Analysis*, 2006. In revision.

[8] Günter Westphal, Christoph von der Malsburg, and Rolf P. Würtz. Feature-driven emergence of model graphs for object recognition and categorization. In Abraham Kandel, Horst Bunke, and Mark Last, editors, *Applied Pattern Recognition*. Springer, 2007. In press.

[9] Marco K. Müller, Alexander Heinrichs, Andreas H.J. Tewes, Achim Schäfer, and Rolf P. Würtz. Similarity rank correlation for face recognition under unenrolled pose. In Seong-Whan Lee and Stan Z. Li, editors, *Proceedings of the 2nd International Conference on Biometrics, Seoul*, LNCS, pages 67–76. Springer, 2007.

Objectives

- Investigate methods for tracking and segmentation of human body parts in “simple” image sequences
- Find constraints between body segments emerging from these segmentations
- Use constraints to be able to analyze more complex image sequences

Objectives

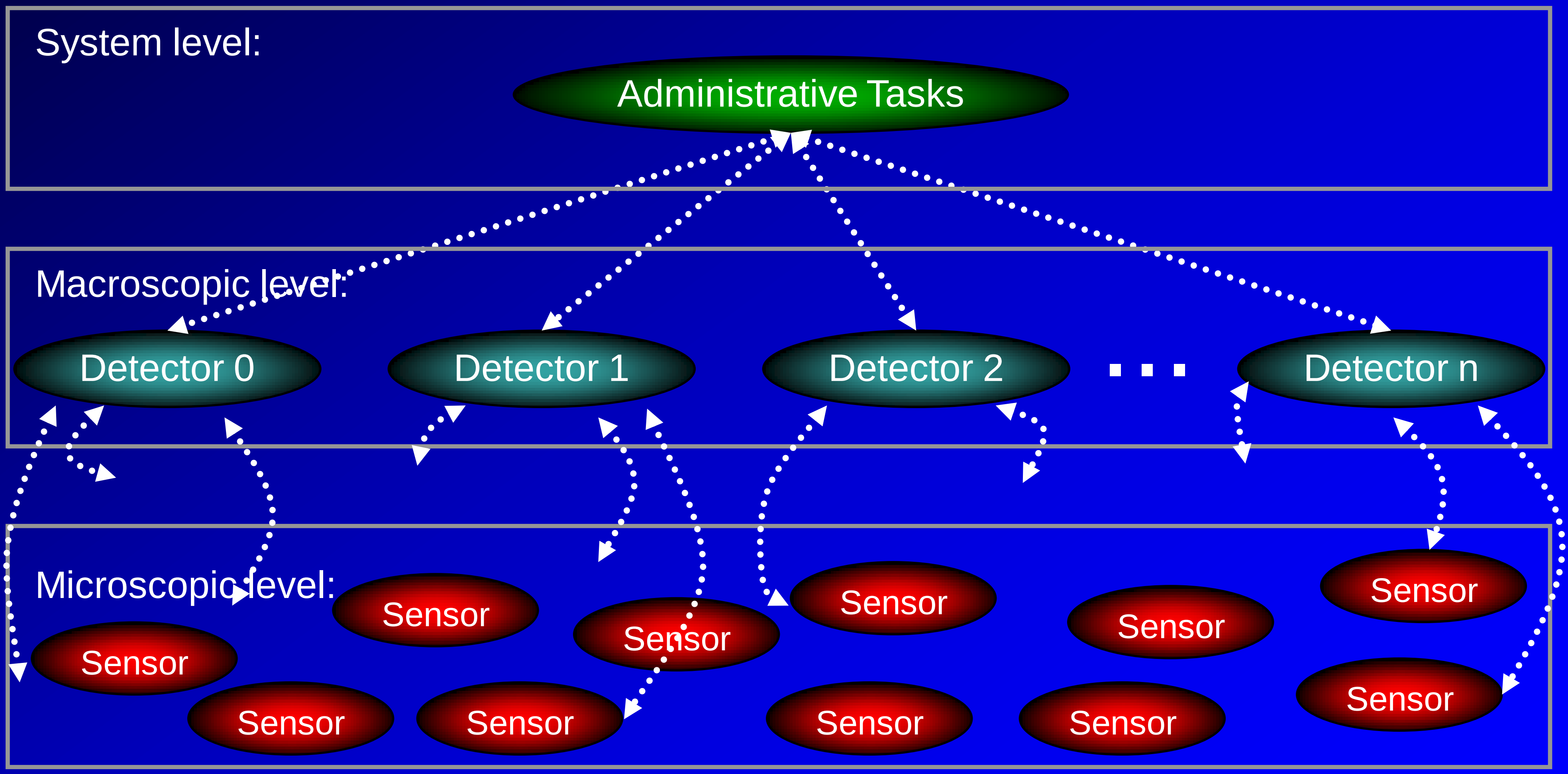
- Real world data - examples:

Retrospect

- Tracking: use many simple image analysis “sensors” instead of few highly specialized ones
- Do not use too much a-priori knowledge, the system should learn from input data
- Let sensors communicate and self-organize to increase robustness and fault tolerance

Retrospect

System hierarchy:



Interlude: Cue Fusion

Maximilian Krüger

Retrospect - Results

Retrospect - Problems

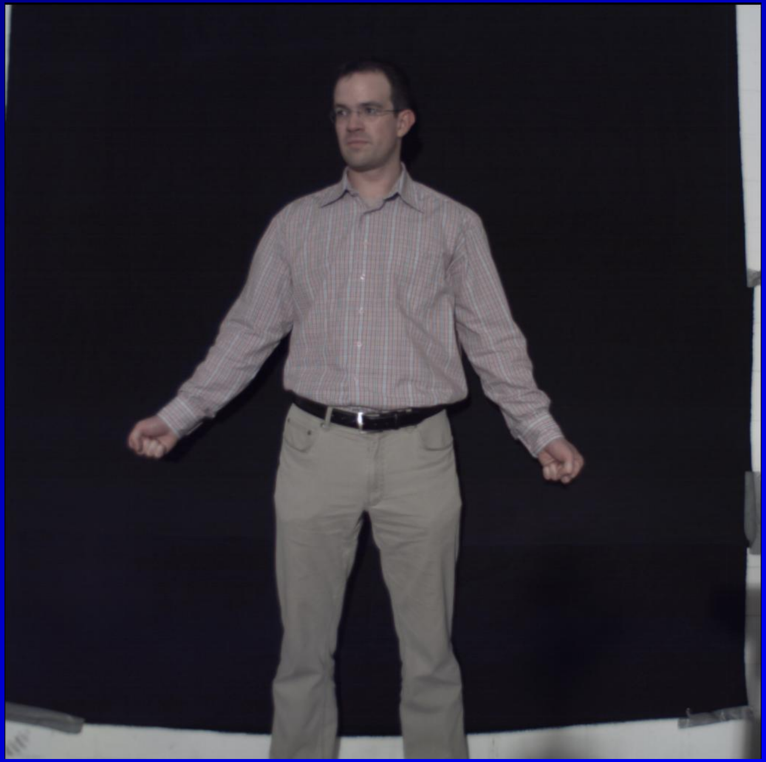
- Problems with multi-sensor approach:
  - Initialization had to be done manually
  - Sensor-flow is difficult to control
  - Sensor grouping was based on local color distribution not on motion coherence
  - Global motion coherence detection is the key to identify human body segments

Prospect: Things to Do

- Automatize feature initialization
- Develop new method to analyze global motion coherence (coarse analysis)
- Use results of this method as basis for enhanced limb segmentation:
  - (Modified) multi-sensor approach
  - (Markov Random Field methods)

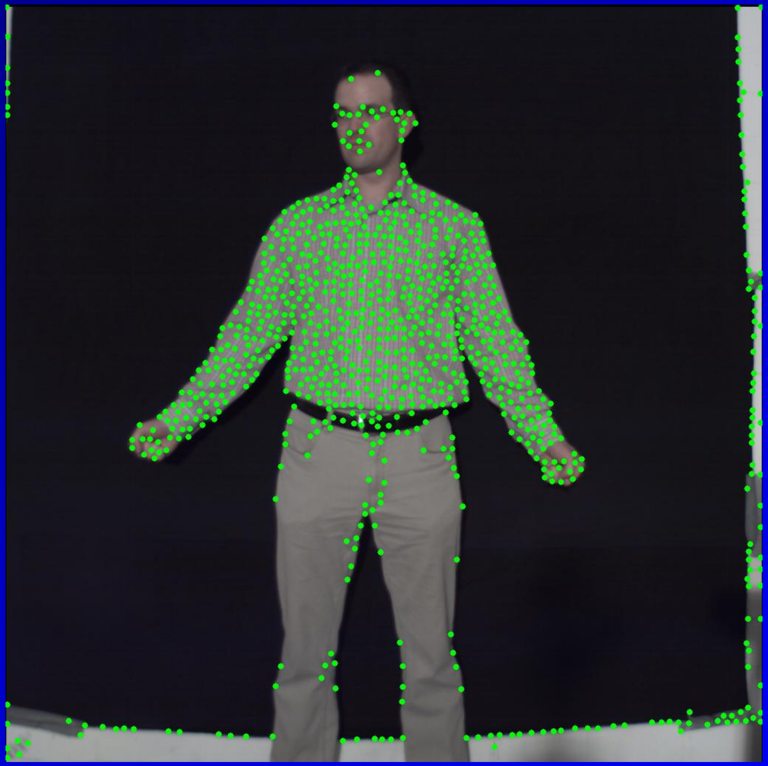
Project Status

- New, high-res (1024x1024), “no clutter” image material: better tracking results with LK algorithm



Project Status

- Automatic feature initialization by finding well-trackable regions via method proposed by Shi and Tomasi 1994

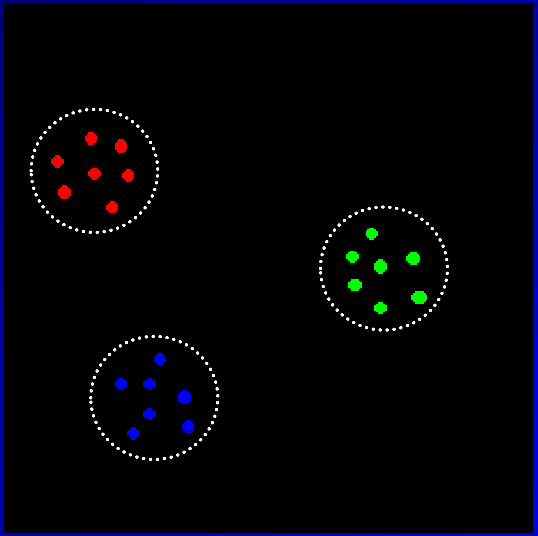


Project Status

- Segmentation of coherently moving limbs:
  - Self-Tuning Spectral Clustering (STSC) (Z. Manor)
    - Performs SVD on feature data to create a „segmentation eigenspace“
    - Rotates found segmentation eigenspace to fit canonical axes, measures quality of best fit (segmentation “score”)
    - No need for (random) initialization
    - Works with data on different scales

Project Status

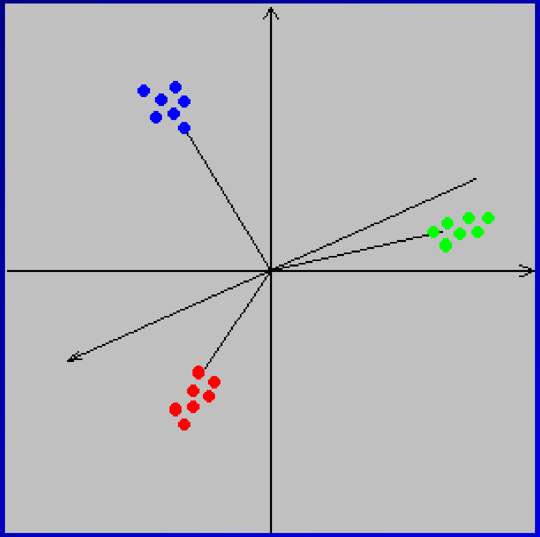
Original dataset



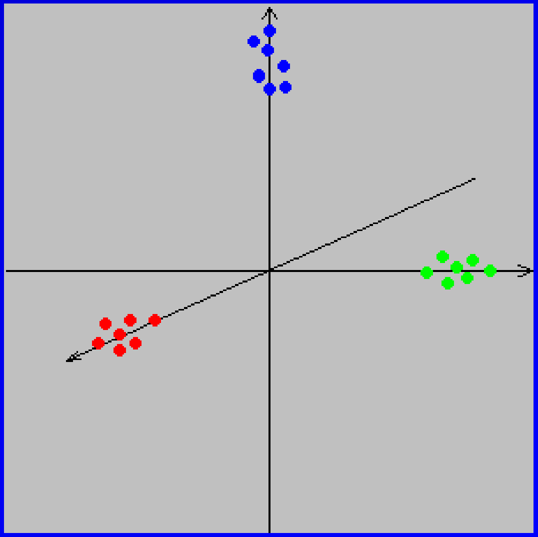
Define „Affinity Matrix“

Segmentation

Transfer to eigenspace (SVD)



Align axes,
retrieve score

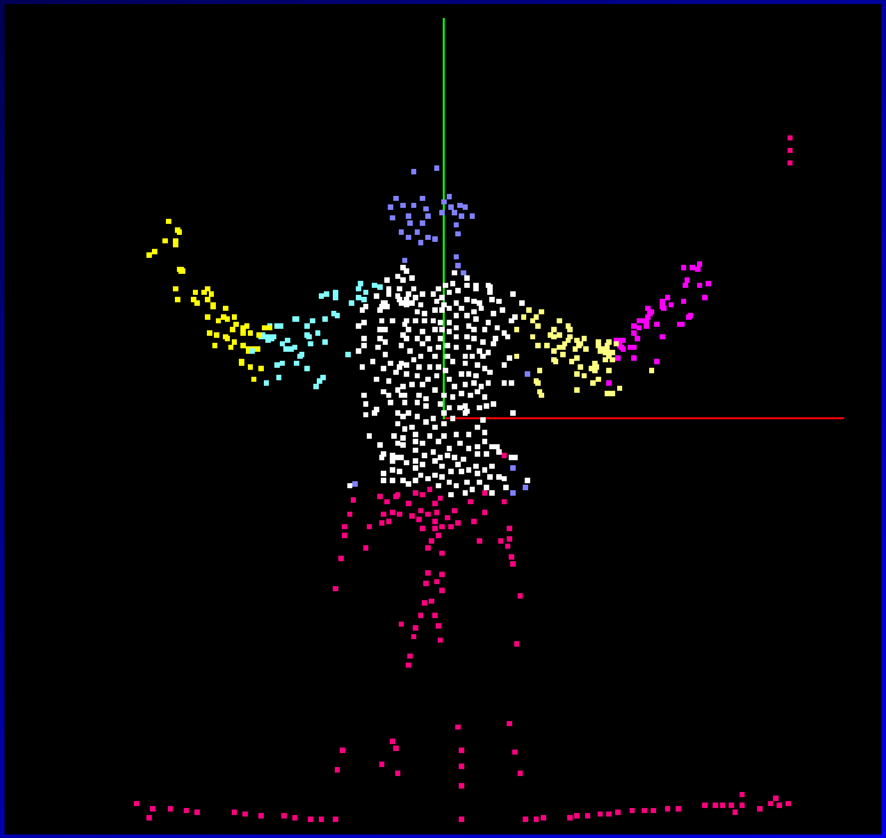


Project Status

- Adapted STSC method:
  - Correct cluster number is not known a-prori, so:
    - Loop over a certain range of possible cluster numbers
    - Segment data via STSC in each frame of the sequence for each cluster number
    - Choose correct number of clusters guided by score values

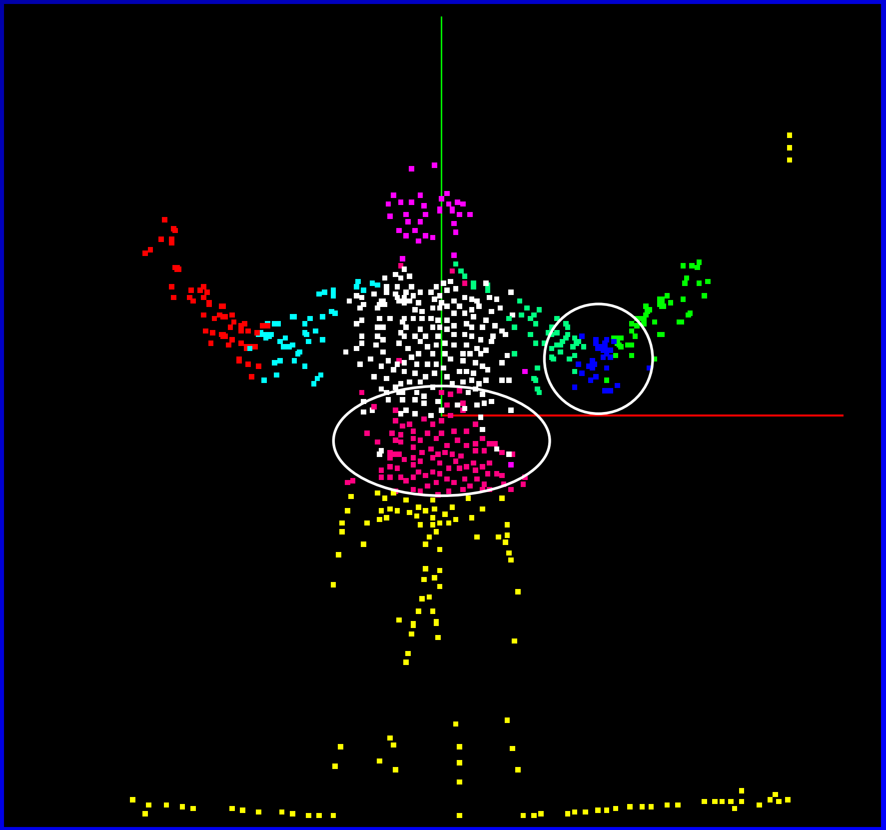
Project Status

Acceptable segmentation



7 clusters, score: 0.979593

Unacceptable segmentation



9 clusters, score: 0.980747

Project Status

- Iterative Bipartite STSC (IBSTSC):
  - For each frame:
    - Initialize queue with complete dataset
      - Retrieve from queue data parent cluster to be split
      - Split parent cluster via bipartite STSC (results in 2 subclusters)
      - If subclusters are “valid”, insert them into queue

        else: store parent cluster as single limb
      - While queue not empty, iterate

Project Status

- Validity of a cluster in IBSTSC:
  - A subcluster is:
    - “valid”, if creating split had a BSTSC score > 0.9
    - “indifferent”, if creating split had a BSTSC score between [0.8;0.9]
    - “invalid”, if creating split had a BSTSC score < 0.8 or if the subcluster is too small (n<5)

Project Status

- "Boosting" a cluster's score value:
  - If subclusters are indifferent, this might be due to outliers in the data (can be identified in eigenspace)
  - Boosting step:
    - Iteratively remove outliers from the parent cluster
    - Perform IBSTSC on the modified parent cluster
    - Stop if score can't be increased anymore
    - Check if score > 0.9 -> subcluster become "valid"

Project Status

- Remaining Difficulties:
  - Parent cluster of a single limb is further split:
    - Folds in clothing can cause “sprite” clusters
    - Since two subclusters <u>must</u> be generated, strange segmentations may occur
  - Normally, such “cloth” or “forced” segmentations produce a poor score value, <u>but NOT always</u>!

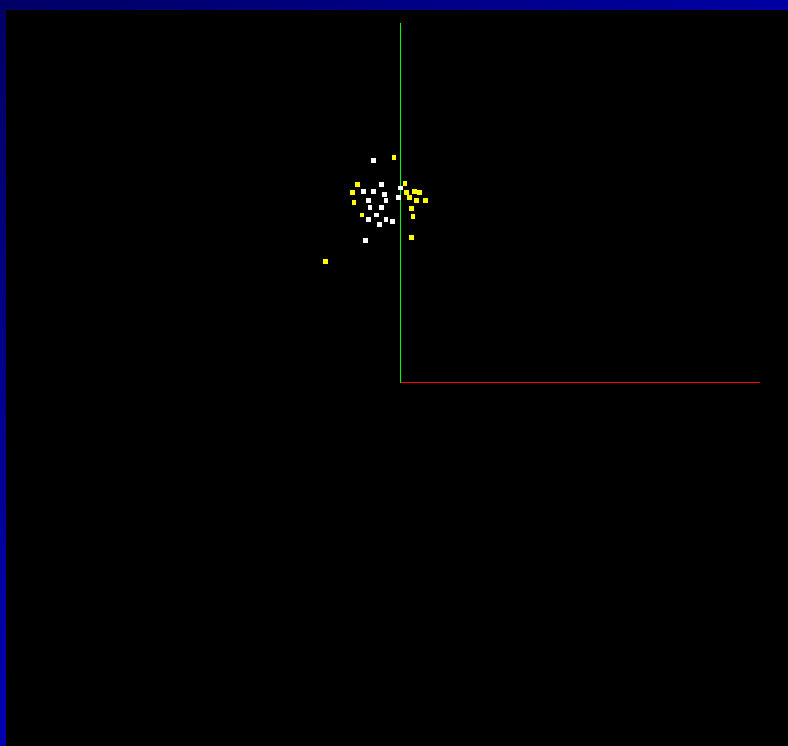
Project Status

- Angular density analysis in eigenspace:
  - Observation:
    - “Normal” splits produce very narrow (sharp) eigenvector distributions
    - “Cloth” or “Forced” splits tend to generate broader eigenvector distrbutions

Use observation to enhance cluster validity check

Project Status

- IBSTSC sample run on human motion data:



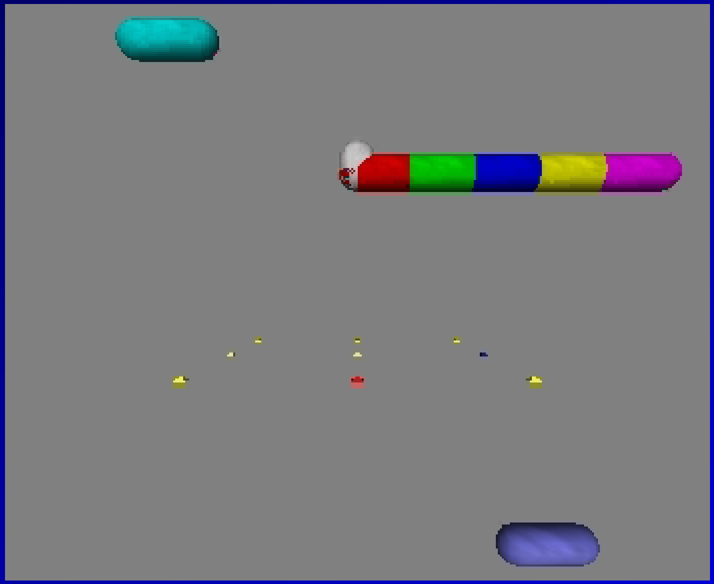
Segment: „[illegible]“

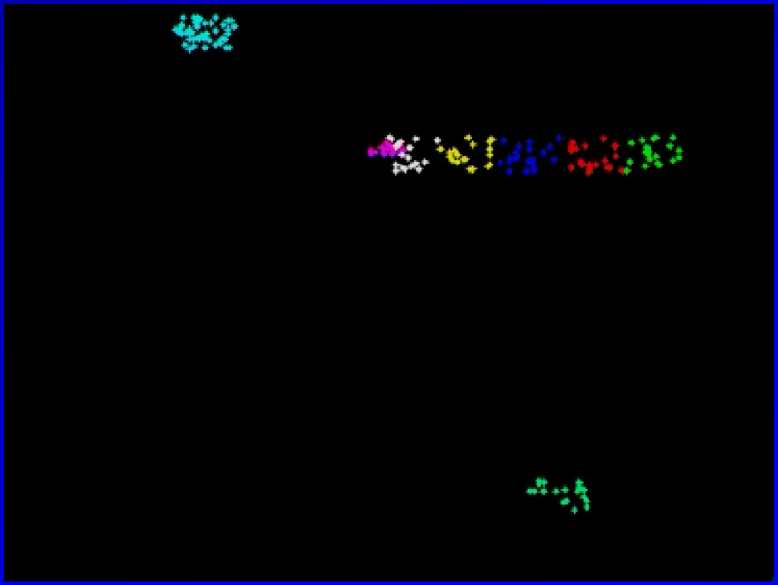
Type: [illegible] split

Split score: 0.[illegible]

Project Status

- IBSTSC sample run on synthetic motion data:





Project Status

- IBSTSC sample run on human motion data:

Project Status

- Summary:
  - When features can be tracked precisely enough, modified IBSTSC finds coherently moving feature groups
  - These groups will serve as basis for further limb refinement
  - IBSTSC produces complex results (segmentations) guided by relatively simple rules

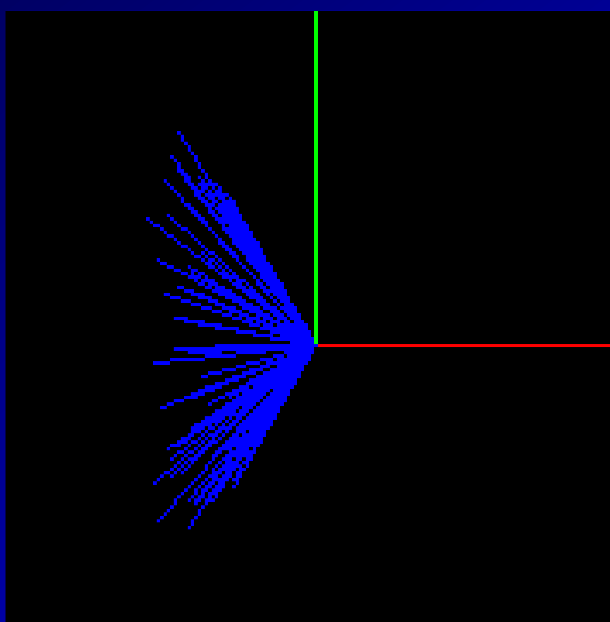
Outlook

- Refine coarse motion segmentation (IBSTSC) with higher-level segmentation methods:
  - Biologically inspired: Multi-sensor approach
  - Conventional: MRF
- Learn limb shape and motion constraints between limbs from fine segmentation
- Use learned shape and motion constraints to track limbs in more complex scenarios

Thank you!

Project Status

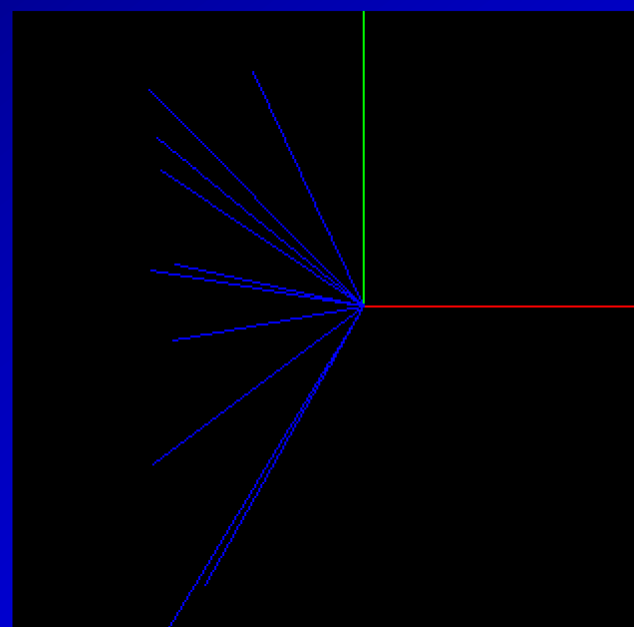
Cloth fold distribution:



Score: ca. 0.98

„Forced split“ distribution:

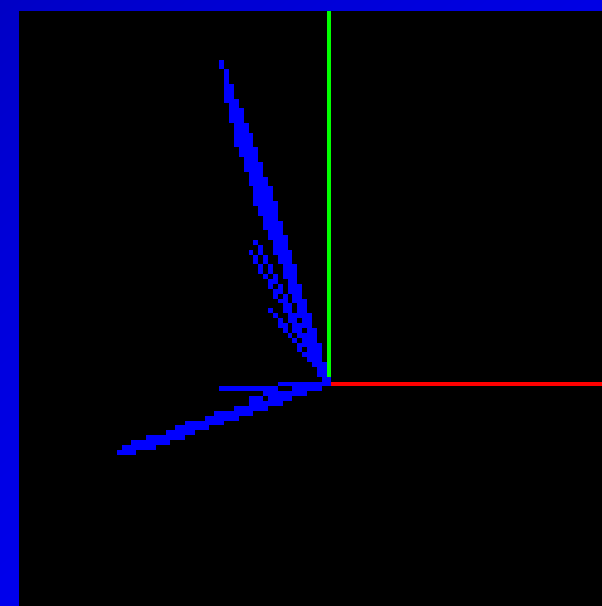
single limb parent cluster



Score: ca. 0.99

Normal split distribution:

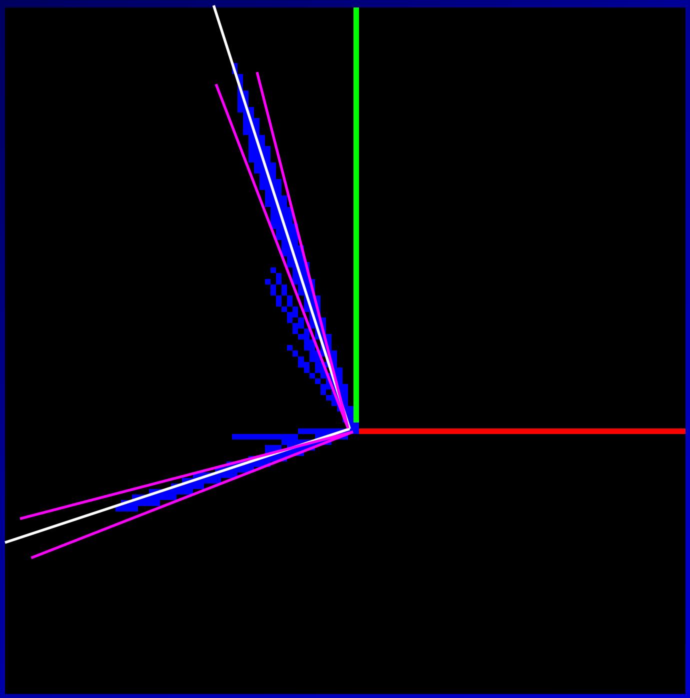
human forearm / upper arm



Score: ca. 0.998

Project Status

- Angular density analysis in eigenspace:



1) Define axes of maximum eigenvector density

2) Count all eigenvectors in 5° cones around axes

3) Divide result by number of all visible vectors

3) Weigh original (old) score value:

$$\text{if } score_{old} < 0.8: \quad score_{new} = e^{-(0.8 - \frac{EVs\,in\,cones}{EVs\,visible})} \cdot score_{old}$$
$$\text{if } score_{old} \geq 0.8: \quad score_{new} = score_{old}$$

Project Status

- Advantages of our method:
  - IBSTSC is already (sparesly) known in literature, see e.g. (???)
    - Cluster number has to be known beforehand for general motion segmentation
    - For certain types of segmentations, “extrinsic” model knowledge can be used to find an iteration stopping criterion
  - A precisely defined “intrinsic” iteration-stopping criterion based on motion information only had still been missing (according to our actual knowledge)
  - “Boosting” and “angular eigenspace analysis” in combination with IBSTSC represent a new approach to close this gap and get a fully intrinsic iteration-stopping criterion that can be used for “quasi parameter-free” generic motion segmentation