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A Movement Tracking Management Model with Kalman Filtering Global Optimization Techniques and Mahalanobis Distance

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  - Simplex Method;
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Introduction

- Motion capture video systems and interactive modelling systems can help automatic analysis and diagnosis of objects movement;
- Many tracking applications may require tracking of several objects simultaneously, and involve problems as their (dis)appearance of the scene;
- To track objects we used:
  - A Kalman filter;
  - Optimization Techniques;
  - Mahalanobis Distance;
  - A Management Model.

Kalman Filter

- Optimal recursive *Bayesian* stochastic method;
- In this work:
  - the system state in each time step is the set of positions, velocities and accelerations of the tracked features (points);
  - new measurements are incorporated whenever a new image frame is evaluated.
- One of its drawbacks is the restrictive assumption of *Gaussian* posterior density functions at every time step;
  - Many tracking problems involve non-linear movement, human gait is just an example.

Mahalanobis Distance and Optimization

- For each position estimate there may exist at most one new measurement to correct its predicted position.
- With Kalman's usual approach the predicted search area for each tracked feature is given by an ellipse (whose area will decrease as convergence is obtained and vice-versa).
  - Some problems:
    - there may not exist any feature in the search area or, as the opposite, there might be several;
    - even if there is only one correspondence for each feature, there is no guarantee that the **best set of correspondences** is achieved.

Mahalanobis Distance and Optimization

- We propose the use of optimization techniques to obtain the best set of correspondences between the predictions and the measures;
- To establish the best global set of correspondences we used the *Simplex* method;
- The cost of each correspondence is given by the *Mahalanobis* distance.

Simplex Method:

- Iterative algebraic procedure used to determine at least one optimal solution for each assignment problem;
- Assignment formulation: one estimate = one measure.

Mahalanobis Distance and Optimization

Mahalanobis Distance:

- Distance between two features is normalized by its statistical variations;
- The *Mahalanobis* distance values will be inversely proportional to the quality of the prediction/measure correspondence; thus to optimize the correspondences, we minimize this cost function.

Mahalanobis Distance and Optimization

Occlusion/Appearance:

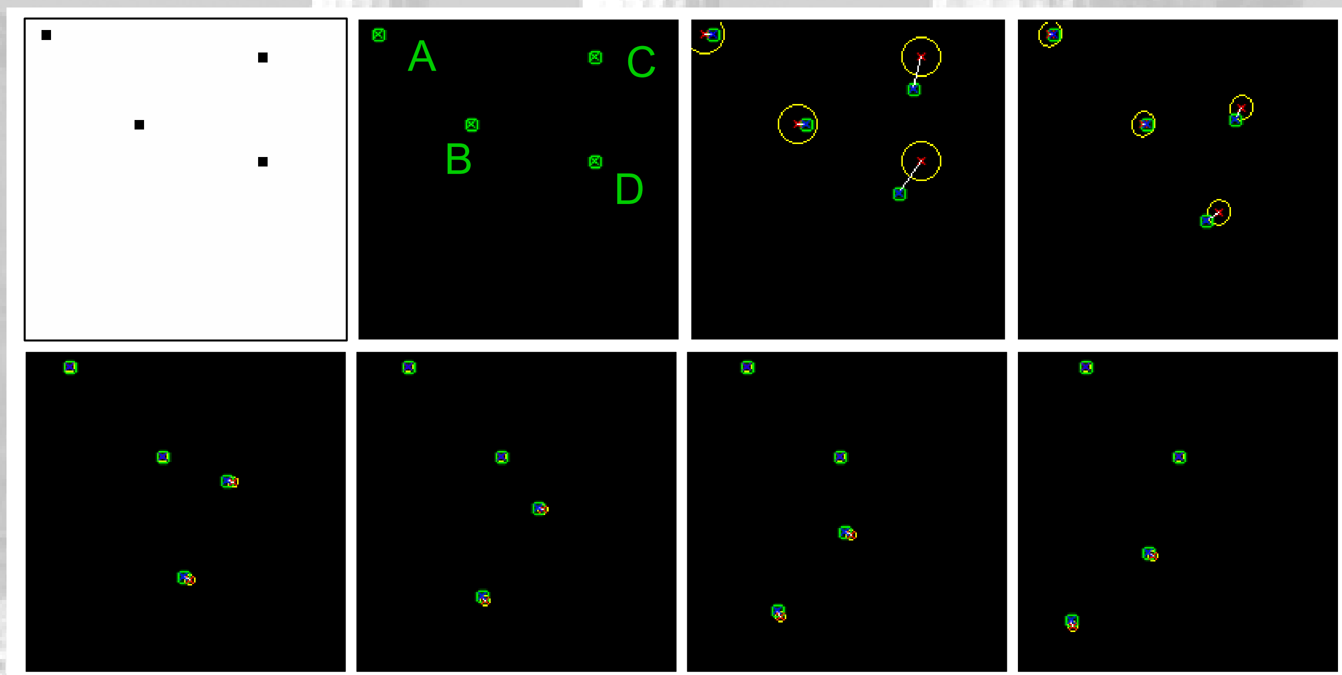
- Assignment restriction (1 to 1) not satisfied – problem solved with addition of fictitious variables:
  - Features matched with fictitious variables are considered unmatched;
  - Unmatched predicted position - it is assumed that the feature has been occluded, but the tracking process is maintained by including its predicted position in the measurement vector although with higher uncertainty;
  - Unmatched measurement - we consider it as a new feature and initialize its tracking process.

Management Model

- When a feature disappear of the scene: Is it just occluded? It was removed definitively? Should we keep its tracking?
- This decision is of greater importance if many features are being tracked, if the image sequence is long, if the tracking is in real-time, etc;
- We use a management model in which a confidence value is associated to each feature:
  - In each frame, if the feature is visible then the confidence value is increased, else it is decreased;
  - If a minimum value of the confidence value is reached then is considered that the feature has definitively disappeared and its tracking will cease (if it reappears, its tracking will be initialised);
  - In this work, the confidence values are integers between 0 and 5, and initialized as 3.

Experimental Results

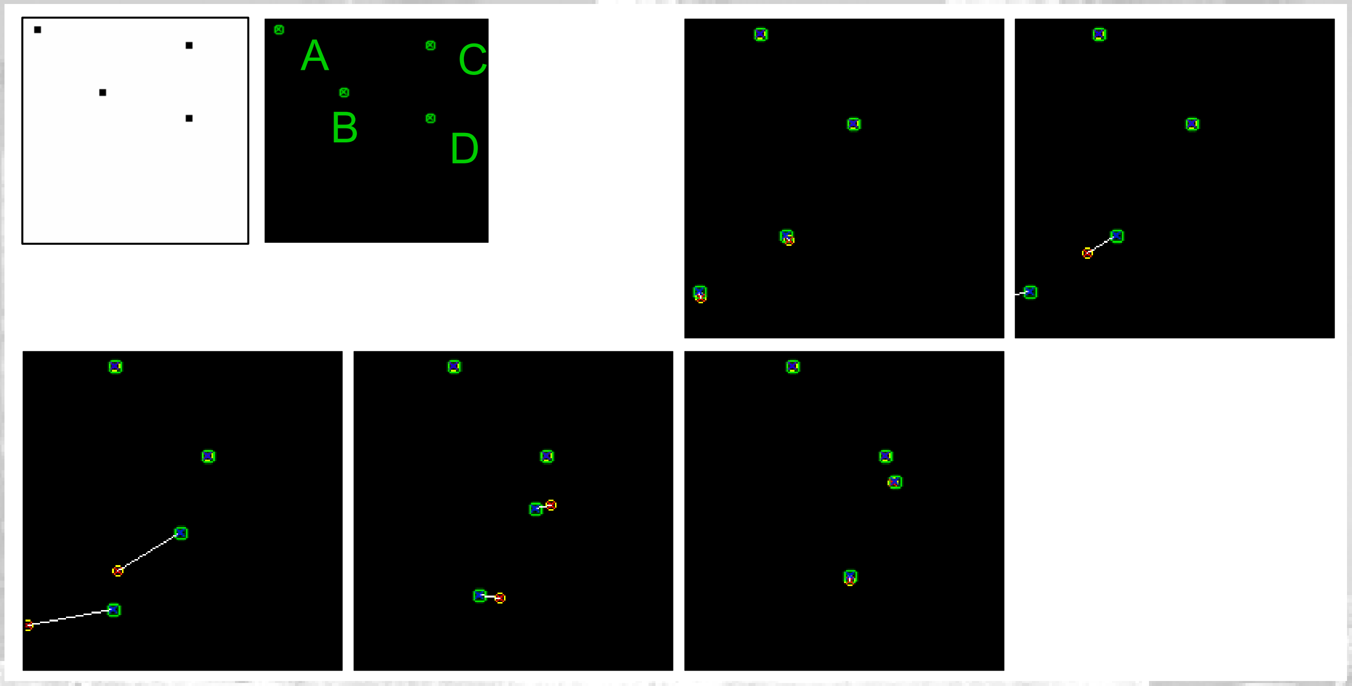
- **Synthetic data**:
  - Points A+B translated horizontally and C+D rotated:

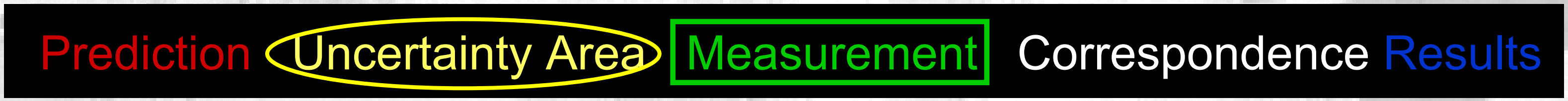


Prediction Uncertainty Area Measurement Correspondence Results

Experimental Results (Cont.)

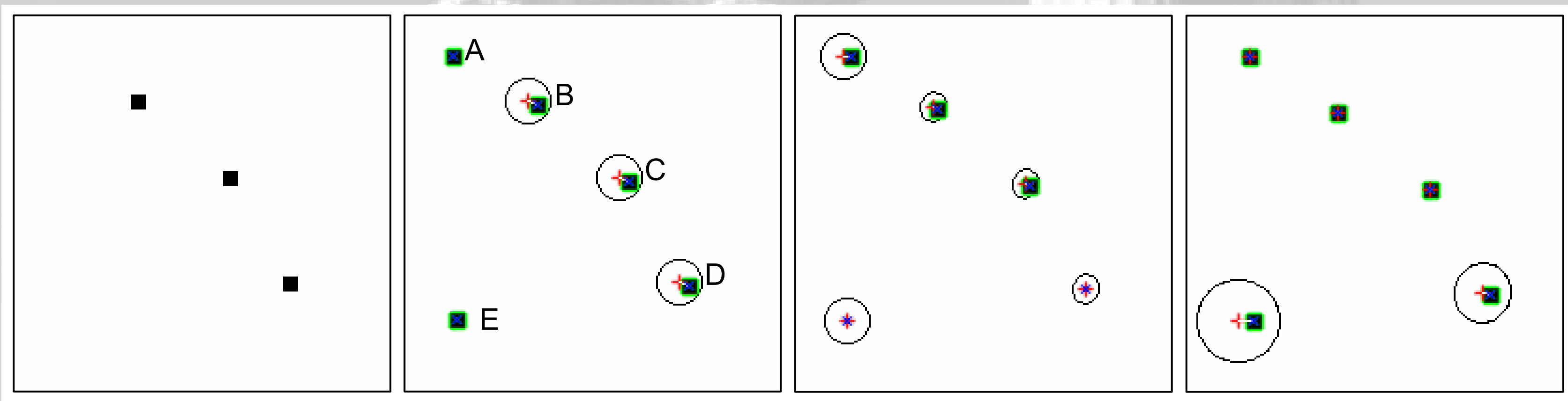
– Continuation. ...Now, Points C+D inverted the rotation angle:

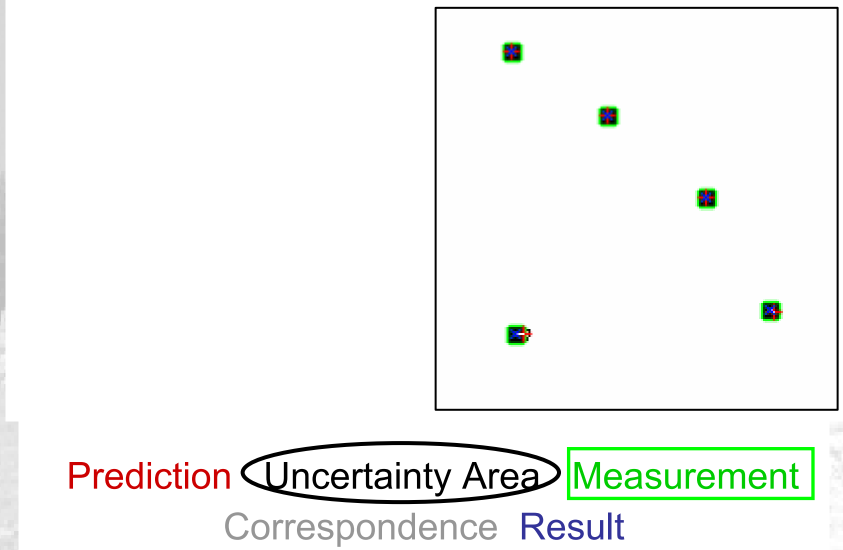




Experimental Results (Cont.)

- Management of the tracking features - blobs (dis)appear randomly:



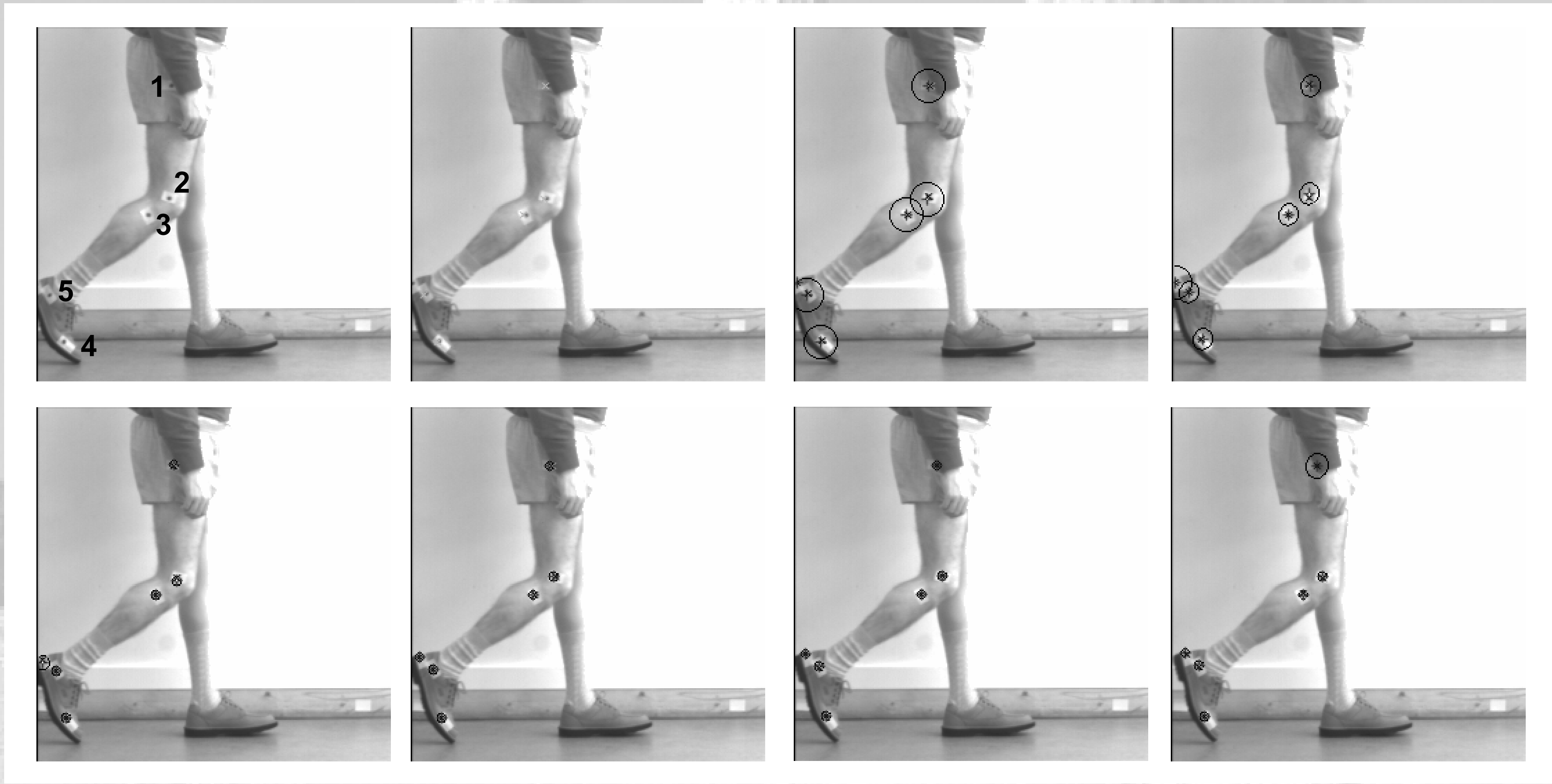


Confidence Values:

Steps / "Blobs"	0	1	2	3	4
A	-	3	4	5	5
B	3	4	5	5	5
C	3	4	5	5	5
D	3	4	3	4	5
E	-	3	2	3	4

Experimental Results (Cont.)

- **Real data**:
  - Tracking 6 markers in human gait:



Experimental Results (Cont.)

• **Real data**:

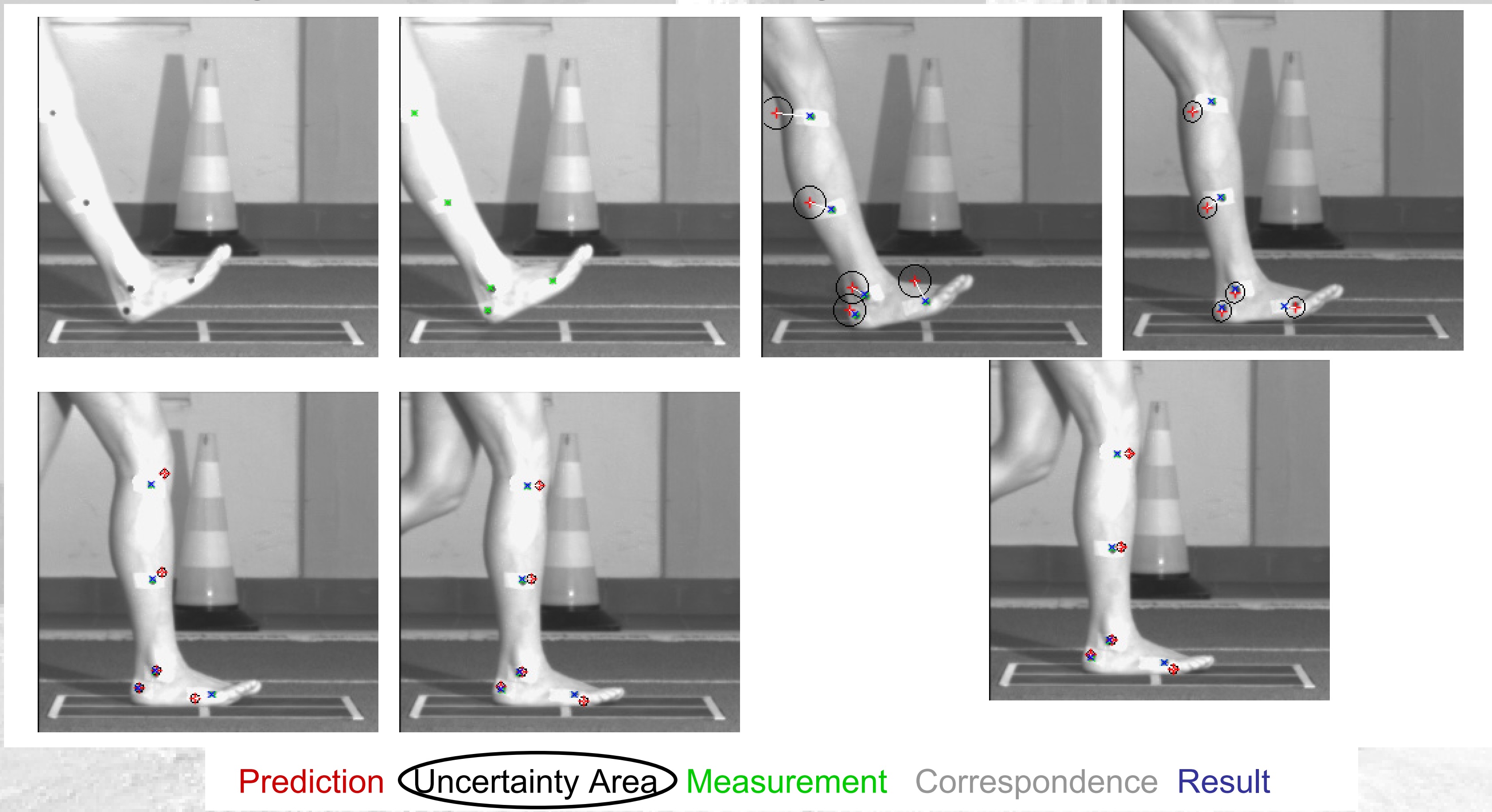
Squared difference between predictions and measures:

Marker \ Step	1	2	3	4	5	6
1	2	1.2	0.9	1.2	-	-
2	2.8	3.3	2.8	1.1	0.7	1.3
3	2	0.8	0.1	1.0	0.2	0.9
4	2.2	1.3	1.3	0.8	0.8	0.8
5	2.2	0.9	0.1	0.0	0.0	0.0
6	-	1	2.2	0.3	1.0	1.5

Average=1.2

Experimental Results (Cont.)

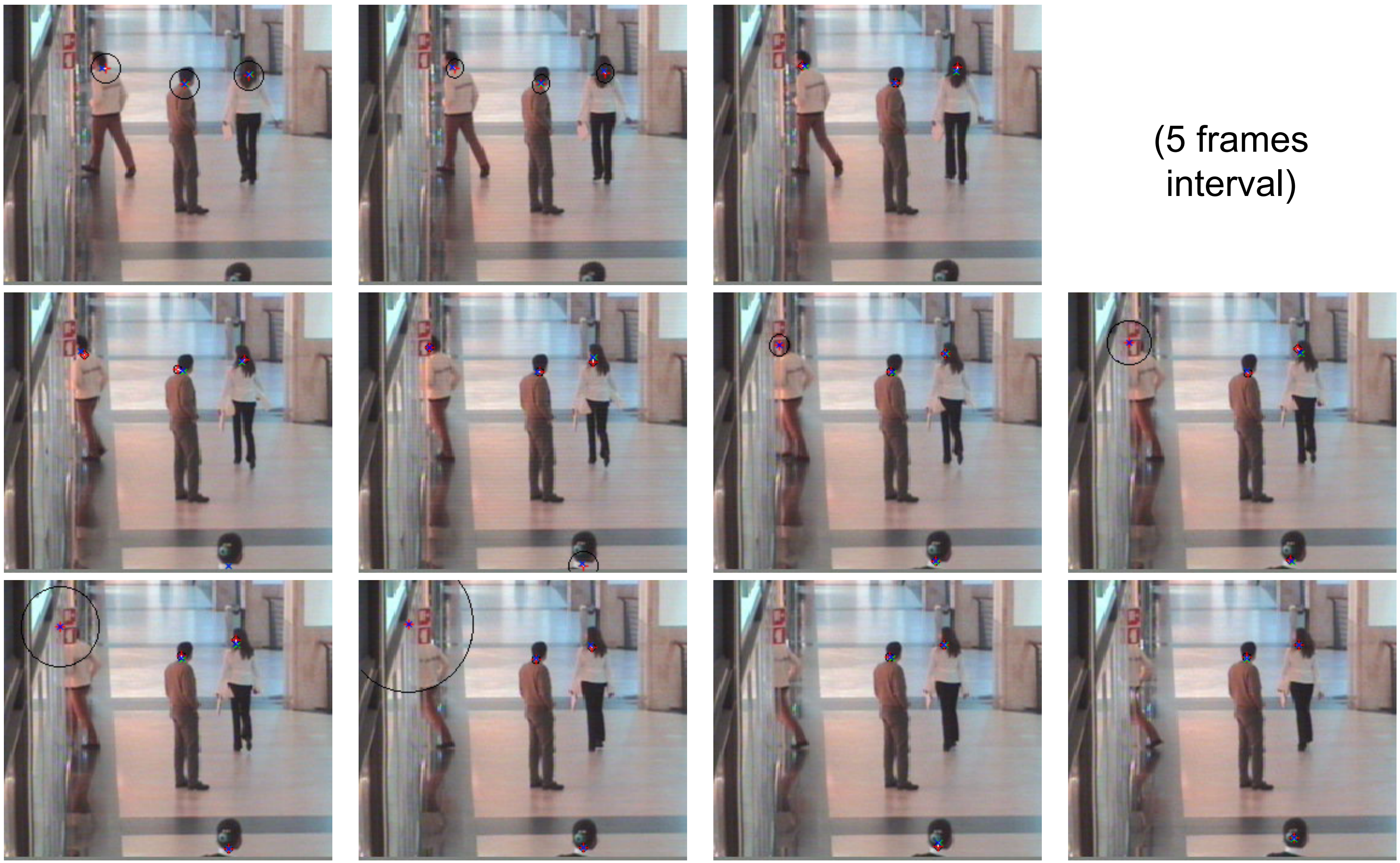
- **Real data**:
  - Tracking 5 markers in human gait:



Experimental Results (Cont.)

•**Real data**:

- Tracking persons in a shopping centre:



(5 frames interval)

Conclusions and Future Work

- We proposed a methodology to track feature points along image sequences based on:
  - a *Kalman* filter;
  - optimization techniques;
  - Mahalanobis distance;
  - a Management Model;
- With our approach, the best set of correspondences is guaranteed (with respect to the used cost function!);
- The used management model allows the tracking in continuous image sequences in real-time, as the features simultaneously tracked are continuously update.

Conclusions and Future Work

Future Work:

- Consideration of other stochastic methods;
- Adoption of matches one to several (and vice-versa);
- Use the proposed tracking methodology in, for example, human gait analysis.

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