Human Movement Tracking and Analysis with Kalman Filtering and Global Optimization Techniques

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Introduction

• Human movement analysis with motion capture video systems and interactive modelling systems can help the automatic analysis, diagnosis, and documentation;
• To track the human movement we use some widespread tracking techniques:
  – Markers;
  – Kalman filter;
combined in this work with optimization techniques.
## Kalman Filter

- Optimal recursive *Bayesian* stochastic method;
- In this work:
  - the system state in each time step is composed by the positions, velocities and accelerations of the used markers;
  - new measurements are incorporated whenever a new image frame is considered.
- 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 markers position estimated by the filter there may exist at most one new measurement to correct it.
• In the *Kalman’s* default approach the search area for each marker position in the image plane is given by an ellipse (whose area will decrease as convergence is obtained);
  – Some problems:
    • there may not exist any marker in the search area;
    • there might be several markers in the same search area;
    • even if there is only one correspondence for each marker, there is no guarantee that the best set of correspondences has been achieved.
Mahalanobis Distance and Optimization

• We propose the use of optimization techniques to obtain the best set of correspondences between the predictions and the measurements;
• To establish the best global set of correspondences with the given estimates we use the Simplex method;
• The cost of each correspondence is given by the normalized Mahalanobis distance;

Simplex Method:
• Iterative algebraic procedure used to determine at least one optimal solution for each assignment problem;
• Assignment formulation: one estimate = one measurement.
Mahalanobis Distance and Optimization

Mahalanobis Distance:
- It’s a Euclidian distance normalised by the statistical covariance;
- The *Mahalanobis* distance values will be inversely proportional to the quality of the prediction/measurement correspondence; thus, to optimize correspondences we minimize this cost function.
Mahalanobis Distance and Optimization

Marker occlusion/appearance during movement:

- Problem: Assignment restriction (1 to 1) not satisfied;
- Solution: add fictitious variables (markers that match with a fictitious variable are considered unmatched):
  - Unmatched predicted marker position - it is assumed that the marker 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 marker and initialize its tracking.
Experimental Results

- Using synthetic data:
  - Points A+B with horizontal movement and C+D with pure rotation:
Experimental Results (Cont.)

• Cont. …Points C+D with invert rotation:
### Experimental Results (Cont.)

- Tracking 6 markers in a human gait analysis:

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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</table>
Experimental Results (Cont.)

Squared difference between each pair prediction/measurement:

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<th>2</th>
<th>3</th>
<th>4</th>
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</table>

Average = 1.2
Experimental Results (Cont.)

- Tracking 5 markers in a human gait analysis:
Conclusions and Future Work

• We have successfully tracked feature markers along image sequences of human gait analyses with:
  – Kalman filter;
  – optimization techniques;
  – Mahalanobis distance.

• This approach also allows the incorporation of new data even if it would be out of the default Kalman search area (e.g. change in movement direction).
Conclusions and Future Work

Future Work:

• Application of this approach in human gait analysis movement image sequences without any markers;
• The consideration of other stochastic methods, dedicated for problems with non-linear movements;
• Processing the tracking data to analyse the undergoing movement, for example to do (semi)automatic human gait analysis.
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