ways of how to perform the piece in question, as the analysed performances may be by different performers and differ heavily in their interpretation style. The system then decides on-line at every iteration how to weigh the curves, effectively selecting a mixture of the curves which represents the current performance best.

7. 'ANY-TIME' MUSIC TRACKING

Our system (see Figure 1 for an overview) also includes a unique feature, namely the ability to cope with arbitrary structural deviations (e.g. large omission, (re-)starts in the middle of a piece) during a live performance. While previous systems – if they did deal at all with serious deviations from the score – had to rely on explicitly provided information about the structure of a piece of music and points of possible deviation (e.g., notated repeats, which a performer might or might not obey), our system does without any such information and continuously checks all (!) time points in the score as alternatives to the currently assumed score position, thus theoretically being able to react to arbitrary deviations (jumps etc.) by the performer.

At the core is a process (the 'Rough Position Estimator', see Figure 1) that continually updates and evaluates high-level hypotheses about possible current positions in the score, which are then verified or rejected by multiple instances of the basic alignment algorithm ('Tracker 1–n', each including its own tempo model) described above. To guide our system in the face of possible repetitions and to avoid random jumps between identical parts in the score, we also introduced automatically computed information about the structure of the piece to be tracked. We chose to call our new approach *'Any-time Music Tracking'*, as the system is continuously ready to receive input and find out what the performers are doing, and where they are in the piece. For more details we refer the reader to [2].

8. EVALUATION

All above-mentioned improvements to the original algorithm were extensively evaluated. We have shown that the resulting system is both more robust and more accurate than the original system. Furthermore we already demonstrated the systems accuracy and reliability live on stage during a real piano performance. For detailed evaluation results we refer the reader to [3], [1] and [2].

9. FUTURE WORK

An important direction for future work is the introduction of explicit event detection into our system, based on both an estimation of the timing and an analysis of the incoming audio frames. This would increase the alignment precision especially for sparse and/or monophonic music.

A possible future scenario would be to extend our 'any-time' algorithm to operate on a whole database of musical pieces, automatically recognising both the piece being played, and the current position. An off-line matching/retrieval scenario related to this has been described in [7]. Practically this will require a clever indexing scheme based on musically relevant high-level features to quickly find those pieces and time points most likely to match the ongoing sound stream.

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