Motion Cyclification by Time x Frequency Warping

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Presentation Outline

- Motion Processing
- Motion Re-timing
- Human Motion Cyclification
- Our Motivation
- Time x Frequency Warping of 1D Signals
- Cyclification of Articulated Figure Motion
- Video / Conclusions / Future Work

Motion Processing

- Modification and reuse of animation parameters

- Examples
  - kinematic and dynamic parameters.
  - motion capture data.

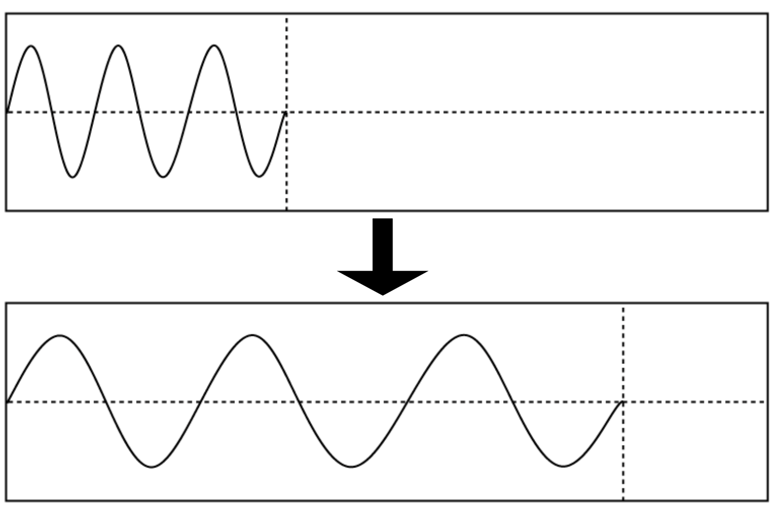
- Strategy
  - signal processing techniques.

Captured Data Processing

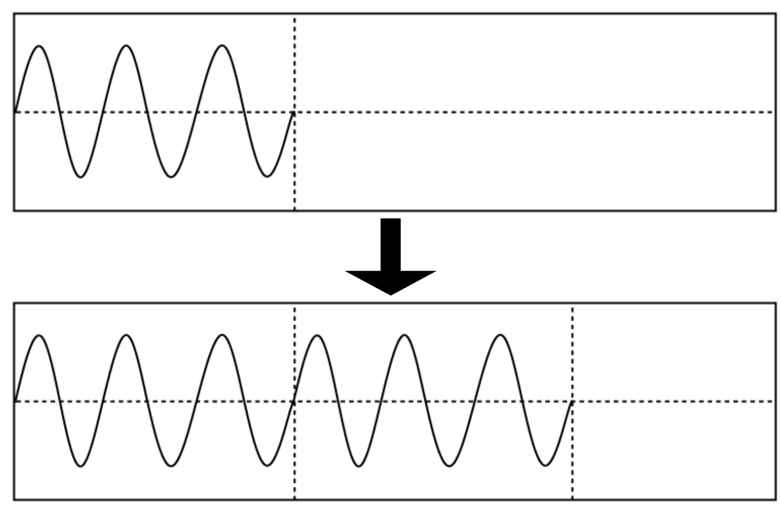
- Motion curves: positional and rotational values
  - sampling at joints of a real subject.
- Current techniques
  - filtering, transition, warping, blending.
- Motion re-timing
  - changes duration of motion (in time).
  - main applications: games, facial animation, ...

Motion Re-timing

- Two different approaches
  - reparametrization
    - local resampling of motion curves ⇨ warping in time domain [Silva et al.98].
    - frequency components are deformed ⇨ slow-motion and accelerated-time effects.



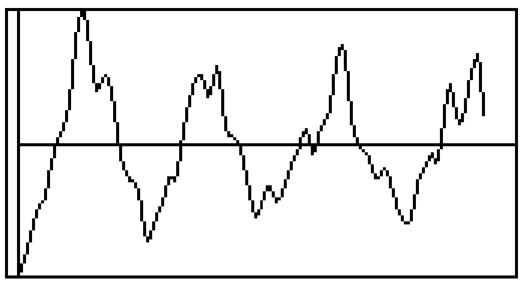
  - cyclification
    - detection and replication of motion cycles.
    - current methods require user interaction and work well only for perfectly periodic motions.



Human Motion Cyclification

- Motion curves have a complex structure
  - *shape*: basic motion patterns (low frequencies).
  - *texture*: subtleties, detail and noise (high frequencies).

- Captured motion curves are not perfectly periodic
  - biomechanic and external factors introduce a noise component fundamental to natural-looking motion [Perlin95].
  - we call this class of motion as *near-periodic*.

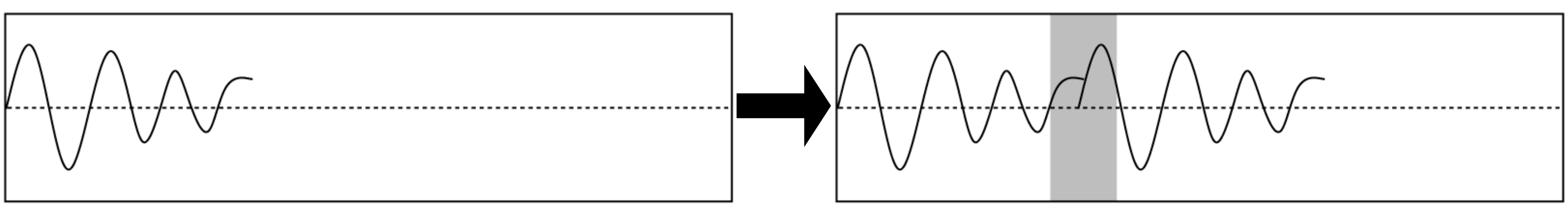


motion captured joint curve
(near-periodic signal)

Detection of Motion Cycles

- Complicated analysis for *near-periodic* motions
  - requires user interaction [Cohen et al.96].
  - not suitable for real-time applications.

- Boundary discontinuity
  - happens during the transition between motion cycles.
  - smoothing methods are required [Sudarsky98].



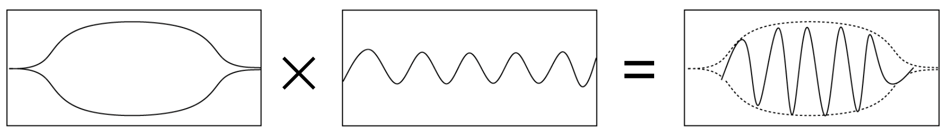
Our Motivation

Develop an automatic method for periodic and near-periodic motion cyclification

- Our choice: warping on time x frequency domain
  - discrete transform: lapped cosine (LCT).
  - frequency contents are not deformed ⇨ “texture” of the movement is preserved.
  - cycles are detected by using an autocorrelation method.

Time x Frequency Decomposition of 1D Signals

- Temporal decomposition into frequency packets
  - cosine transform.

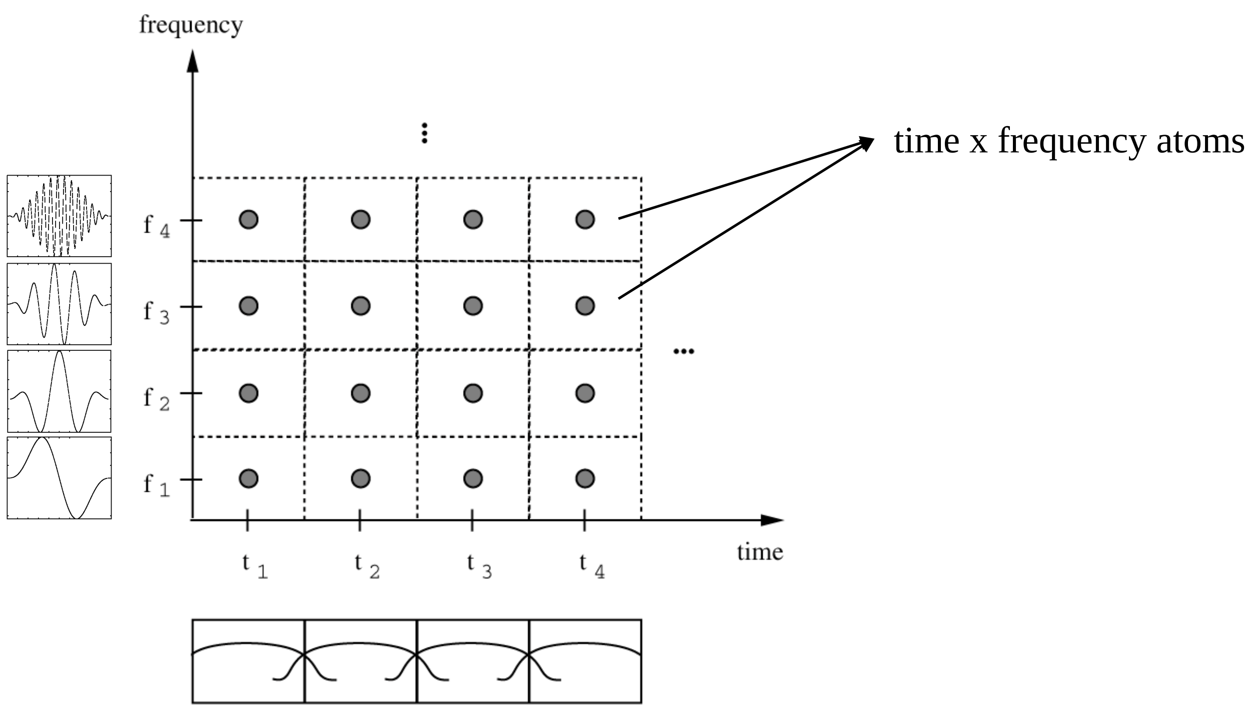


time window frequency modulation smooth cosine window

- Lapped cosine transform (LCT)
  - orthonormal basis.
  - window overlapping ⇨ reduces boundary discontinuity.

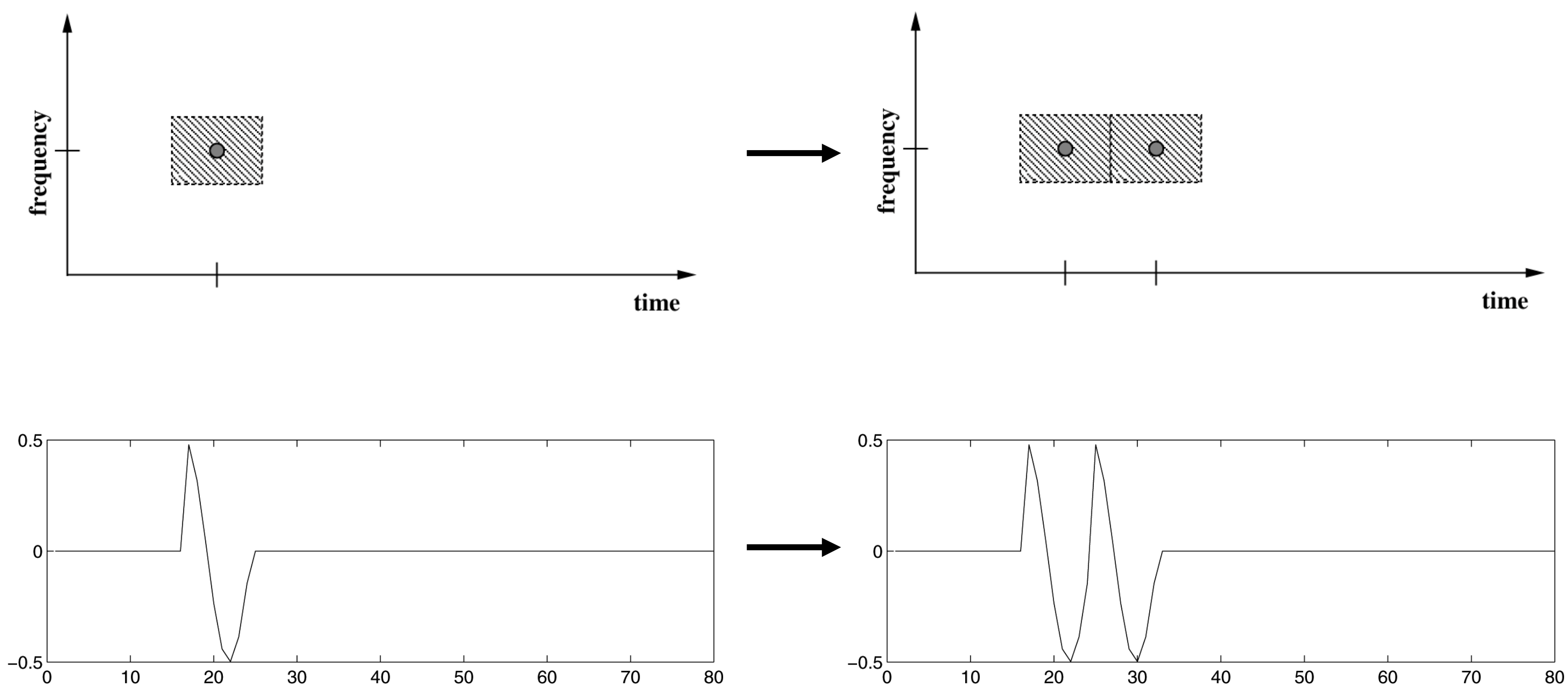
Time x Frequency Representation of 1D Signals

- Finite partition of the time x frequency plane
  - vertical axis: frequency elements of the LCT basis.
  - horizontal axis: overlapped time windows.

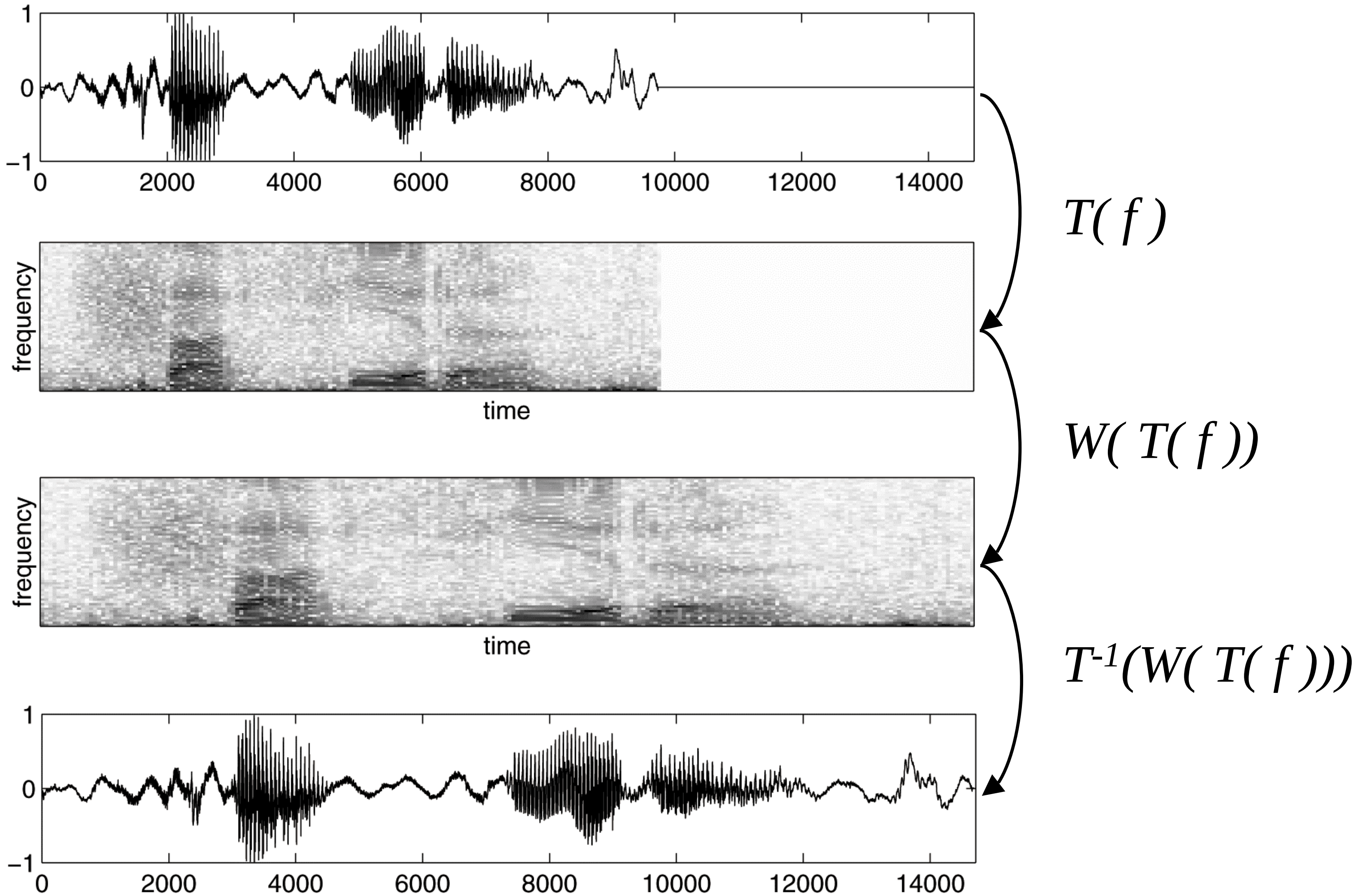


Time x Frequency Dilation of 1D Signals

- Affine dilation on the time axis
  - replication of atom elements of the time x frequency representation.

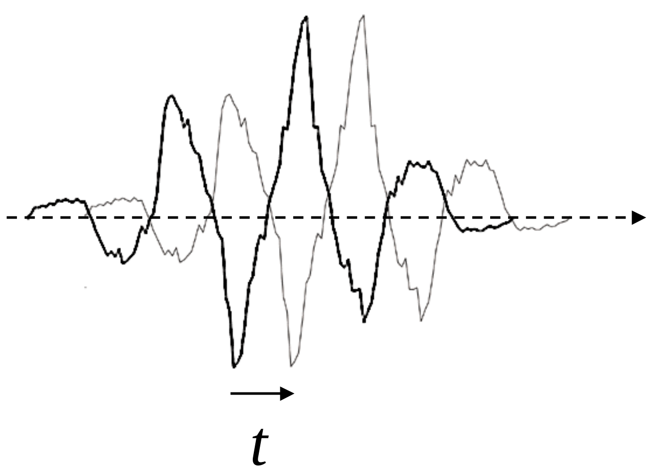


Time x Frequency Warping of 1D Signals

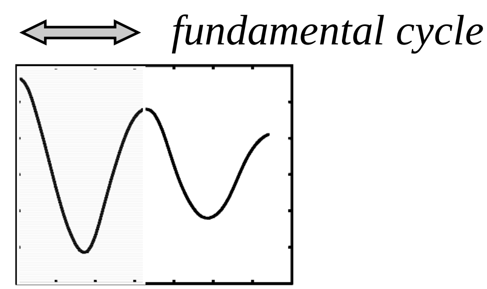


Automatic Cycle Detection

- Fundamental cycle (FC)
  - circular autocorrelation method: measures the similarity between translated versions of a signal.
  - FC is given by the distance between consecutive maximum points.
  - lowest frequency in the signal.



$$\int f(u) \, . \, f(u-t)$$



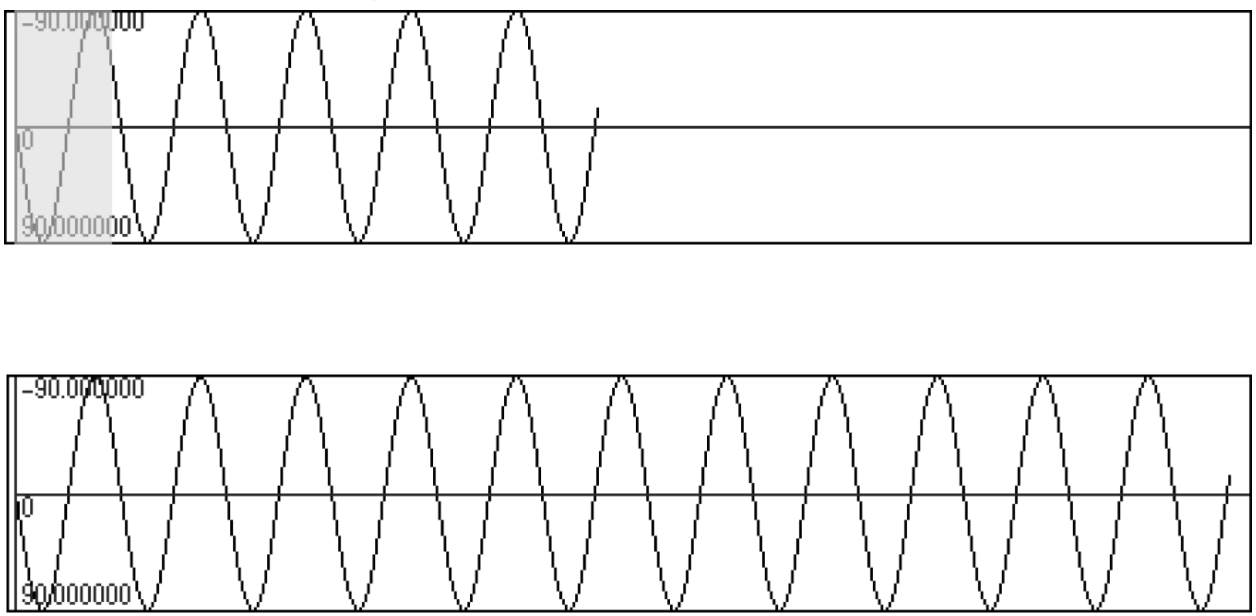
Experiments (1 DOF)

- Re-timing with warp factor = 2.0
- Tests with sinusoidal functions
  - *sine* with fixed period.
  - *sine* with variable period and window size.
- Kinematic simulation of a pendulum
- Left upper arm joint motion curve

Experiment #1

– *sine* function with fixed period.

FC detected by the algorithm

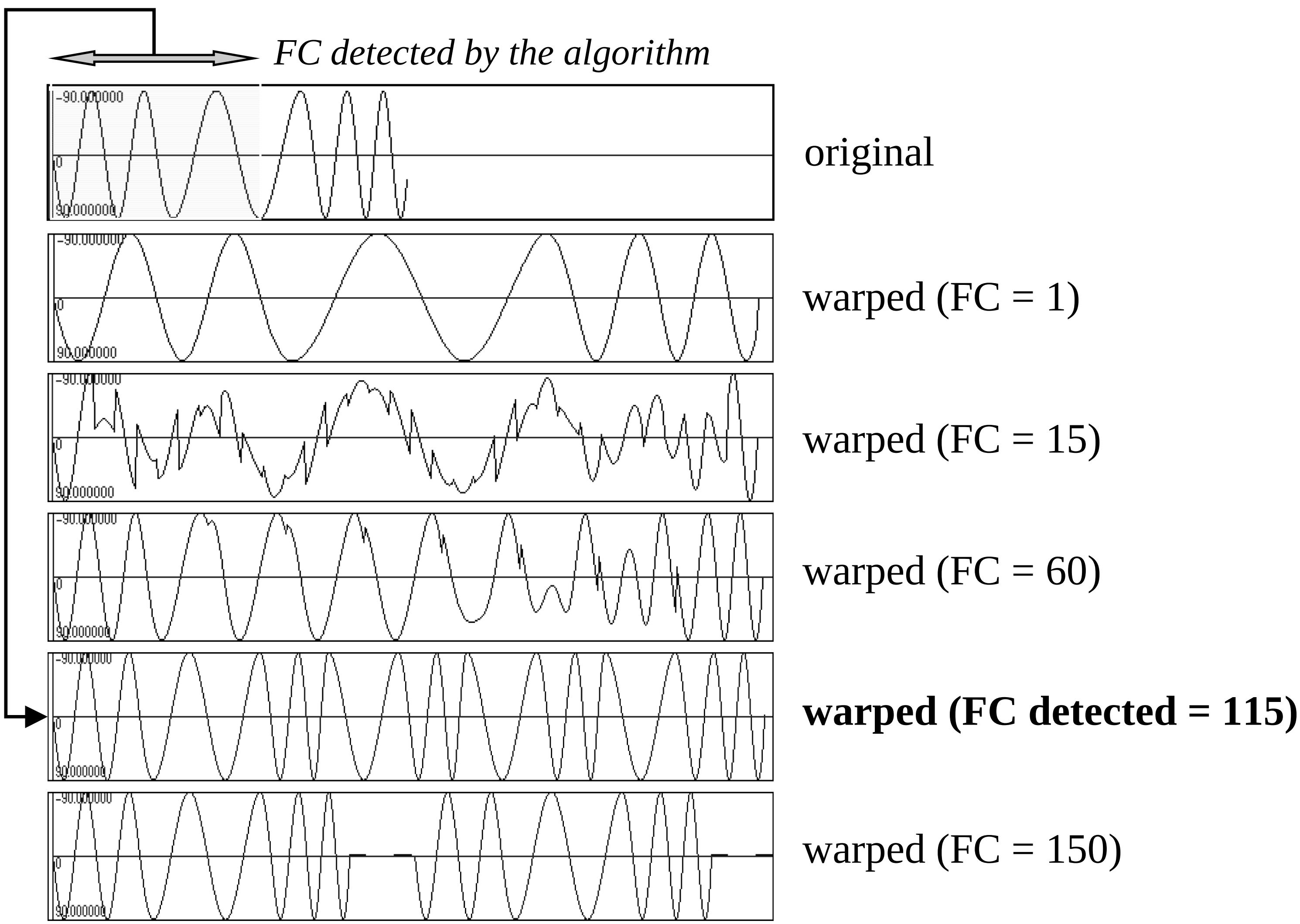


original

warped

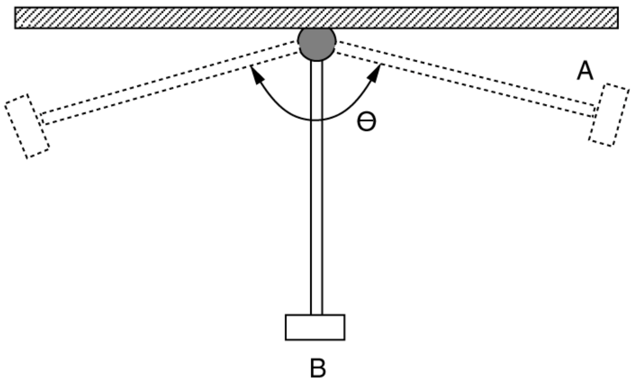
Experiment #2

– *sine* function with variable period and FC.

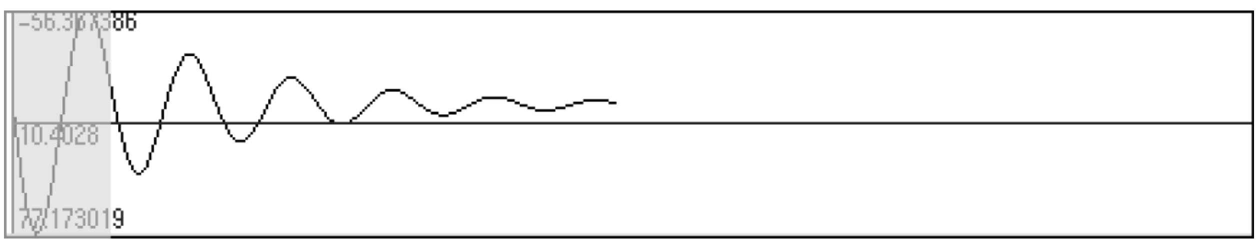


Experiment #3

– kinematic simulation of a pendulum.



⟺ *FC detected by the algorithm*



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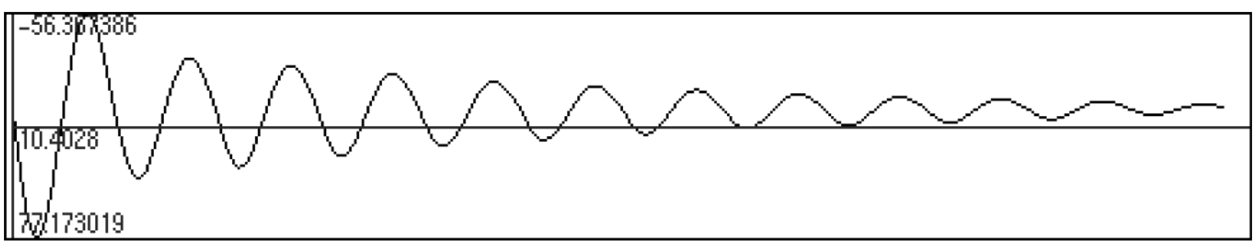
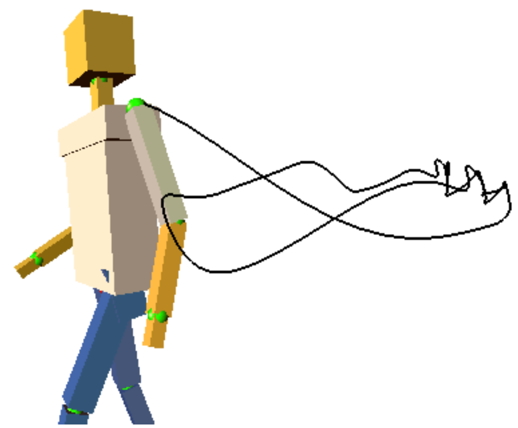
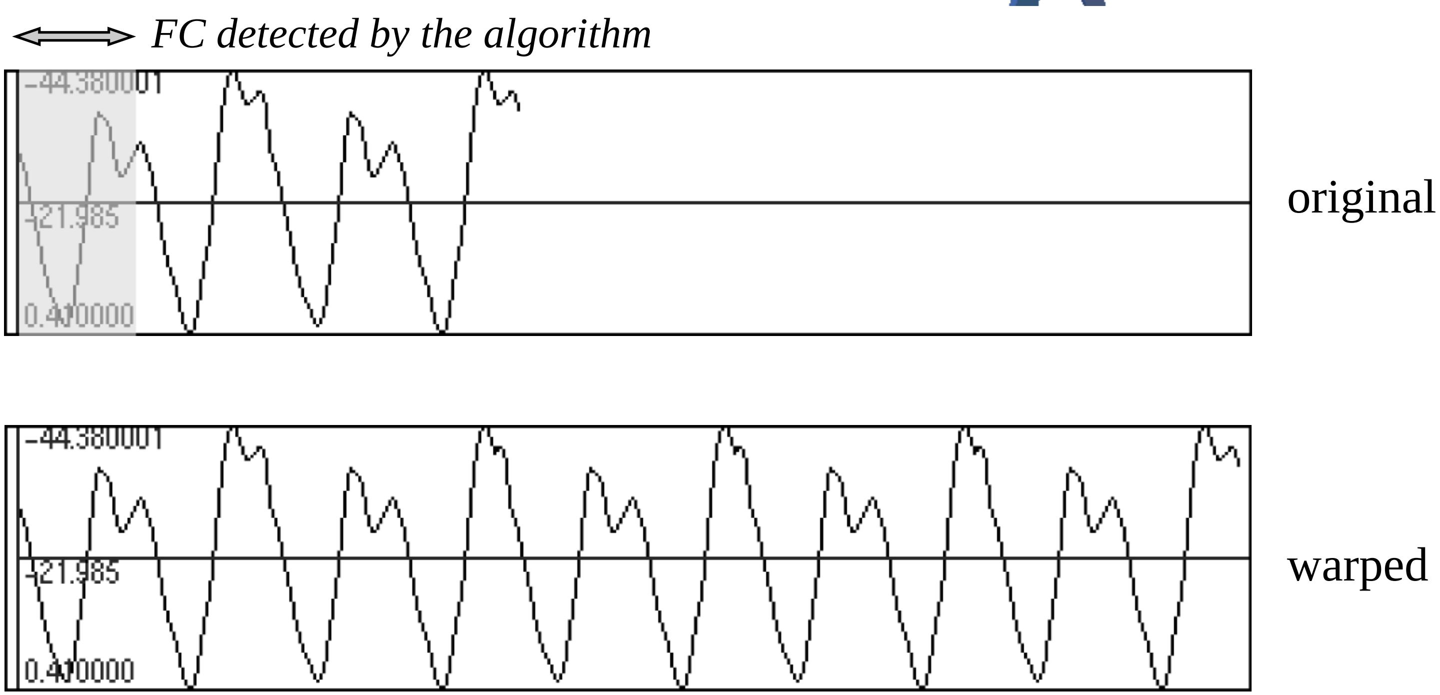


warped

Experiment #4

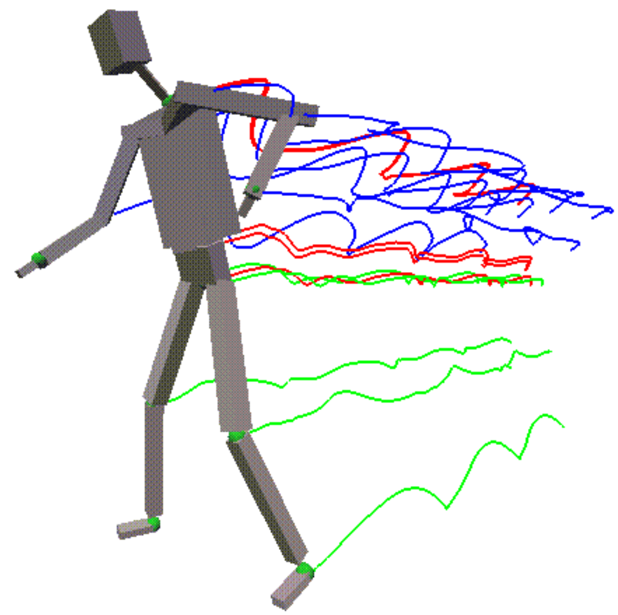
– left upper arm joint motion curve.





Cyclification of Articulated Figure Motion

- Articulated figure: complex structure
  - multiple joints and DOFs.
  - large amount of data to process and control.
  - *near-periodic* motions: synchronism between joints must be preserved by the warping algorithm.

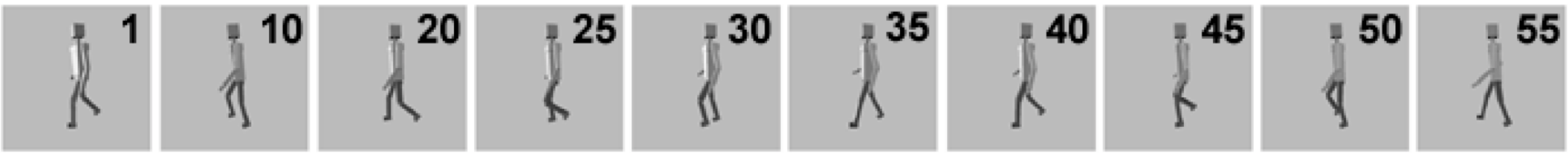


Strong and Weak Phase Dependence

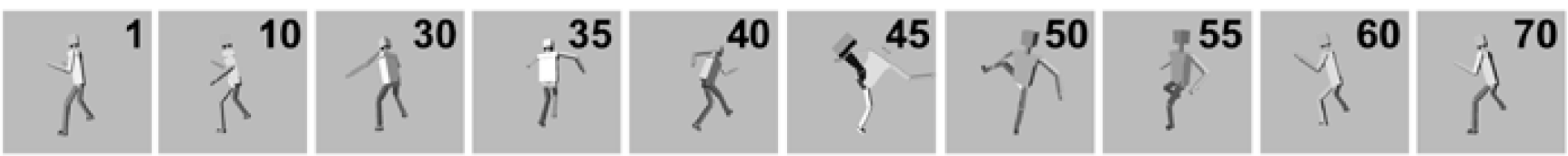
- Strong
  - direct structural relationship between joints (e.g. motion of knee and foot is influenced by upper leg joint motion).
  - common periodic behavior ⇨ phases are multiples of a predominant FC.
- Weak
  - indirect structural relationship between joints (e.g. motion of arms and legs).
  - happens due to balance and stability control.

Strong and Weak Phase Dependence

- Walk sequence
  - strong dependence between outer and inner joints in arms and legs.
  - weak dependence between arms and legs (cross synchronization).



- Backflip kick sequence
  - strong dependence between outer and inner joints in arms and legs.
  - weak dependence between arms and legs (coupled synchronization).



Detection of Predominant Cycle

- For each group of joints
  - apply autocorrelation method to all motion curves, generating a set of FCs.
  - take the greater FC.
  - warp all motion curves within joint group using as input the selected FC.

Conclusions

- New technique for cyclification of motion curves
  - time x frequency warping algorithm.
  - preserves the *shape* and *texture* of the curves.
  - works well with periodic and *near-periodic* curves.

- Cyclification of articulated figure motion
  - analysis of strong and weak dependencies between body segments.

- Video with results

Future Work

- Algorithm extension and improvement
  - complex human figure motion.
- Synchronization of facial animation and audio
  - non-linear audio editing.
  - film dubbing (lip-sync).
- Integration of method on a full animation system
  - transform simultaneously human motion, facial animation and sound.

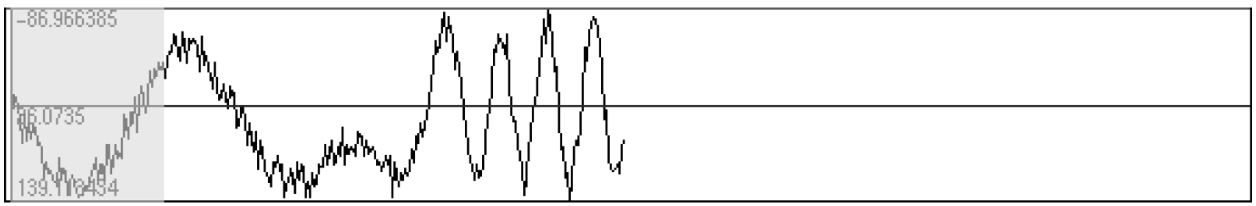
Additional Info

http://www.visgraf.impa.br/mocap

Experiment #3

– *sine* function with variable period and noise.

FC detected by the algorithm



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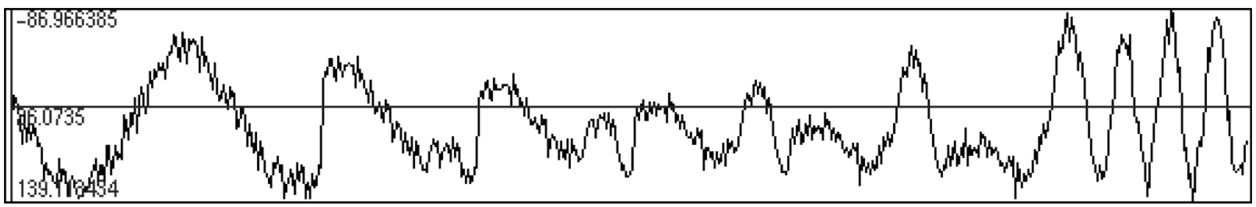

warped