**On Compositional Image Alignment**  
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**Contribution: Fast and reliable Face Alignment**

Inverse compositional image alignment (ICIA) is fast but not reliable. We explain ICIA from a different perspective which leads naturally to two new algorithms with a better capture range and comparable speed.

**There is no inverse in ICIA**

Image alignment minimizes

\[ F(q) \triangleq \| f(q, \beta) \|_F^2, \]

with \( f(q) \triangleq \alpha - (I \circ W(q)) \)

composition with an incremental warp \( V \) approximates \( F \) around \( q_0 \) as

\[ F(C^0(q_0, p)) \approx \tilde{F}(q_0, p) \triangleq \| \tilde{f}(q_0, p) \|_F^2 \]

with \( \tilde{f}(q_0, p) \triangleq p(\alpha - (I \circ W(q_0)) \circ V(p)) \)

The gradient descent or Gauss-Newton update rule then gives an estimate of the incremental warp, which drives the model warp.

ICIA can be derived by substituting the current backwarped image with the model appearance after taking the derivative. The substitution can be used to get an approximate gradient and/or Hessian, leading to a family of algorithms.

Additionally we replace the incremental warp \( V \) with an orthonormalized warp and regularize in the composition step. The result is a vast improvement in robustness without sacrificing speed.

**Training + Testing Data**

The model was trained from 456 images from the IMM and XM2VTS datasets using 120 landmarks. Get the landmarks, model, and source code at: [www.cs.unibas.ch/personen/amberg_brian/aam/](http://www.cs.unibas.ch/personen/amberg_brian/aam/)

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**Low Res Tracking**

- **ICIA with VOrtho**
- **LinCoDe**
- **CoDe**

Tracking a low resolution video with large head motions succeeds with CoDe, where ICIA fails. All methods used the orthonormal incremental warp, and relatively strong regularisation. ICIA starts to drift in the early frames, while CoDe tracks the full sequence. The approximate gradient method LinCoDe also succeeds, but looses track of the details for about 100 frames.

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**REFERENCES**


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**Our Methods are at the Performance/Speed Sweet Point**

Fitting a multiperson AAM. The best speed-performance tradeoffs come from the two new algorithms CoDe and LinCoDe. Note that ICIA is practically useless on this difficult multi-person dataset with a success rate near zero (left). It can be improved (right) by using the orthonormal incremental warp and regularisation. The CoDe algorithm with regularisation (right) is as accurate as the slow, approximation-free, compositional Gauss-Newton CoNe method but is seven times more efficient. The experiments were performed with leave one identity out on a mixture of two databases (XM2VTS and IMM).

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**Tracking 5000 frames with a general model**

Our algorithm makes fast and robust tracking possible. We compare face tracking under natural motion, using ICIA, LinCoDe and CoDe. The original ICIA fails immediately with this large model and new face data. Substituting the orthonormal incremental warp for the original ICIA warp, the algorithm still loses track very early, whereas LinCoDe and CoDe can track much further. Finally, adding regularisation to all algorithms, ICIA still loses track completely after approximately 500 frames and does not recover the local deformations accurately. In contrast CoDe now tracks the full 5000 frame sequence without reinitialization, and LinCoDe tracks for 2500 frames.

The same training dataset was used for both tracking experiments. The training data was acquired with different camera and light settings from different subjects.