High Efficiency CT (HECT) ™, [1] for Automated Alignment and Contrast Calibration of Projections in Quantitative TEM Tomography

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High Efficiency Computed Tomography (HECT) using a Bayesian approach to 3D density estimation is an efficient new estimation technique that solves two key issues of present TEM CT: speed and accuracy [1]. This technique is expanded to perform 3D density estimation and the fitting of the projection images in terms of the *alignment* as well as their *contrast*.

Others [2,3] have demonstrated the usefulness of correlation techniques to align projections. A conceptually similar approach is used by minimizing the residual error between the (logarithmically transformed) projection data (Fig. 1) and the HECT prediction. However, significant mismatches become apparent when aligning the predicted and measured projection data: in some projection directions high density areas show positive residual errors while in others the same high density areas yield negative residuals (Fig. 2).

Mismatch of the projection densities in different directions is not surprising considering automated exposure control which changes the effect of the dark-current level. Additionally, scatter and imaging non-linearities may change the relationship between the actual image contrast and that predicted by Beer's law.

Here we demonstrate an approach to estimating image alignment together with a correction to the measured image contrast in a biochemical bacterial-mineral association study [4].

The approach performs an initial 3D HECT of the un-aligned projections. Using perturbation of the predicted projections allows to obtain correction factors (shift – and if desired image warping) which are then used iteratively to obtain updated 3D HECT densities with their corresponding 2D predictions. When the alignment corrections become less than single pixels the same perturbation concept is applied alternatingly to the parameters of the logarithmic transformation. This transformation accounts for the dark current and the beam intensity. Stability considerations suggest performing the initial alignment prior to contrast adjustment. The effect of alignment and contrast correction is shown in Fig. 3. The scatter plot demonstrated the linearity between the predicted and original projection data. For these studies a subset of only 9 to 18 (of 81) projections was sufficient.

In summary, HECT is an efficient estimation technique that solves two key issues of present automated quantitative TEM tomographic reconstruction: image alignment and contrast calibration.

References

[1] Jarisch W.R., Microscopy and Microanalysis, Albuquerque, NM. Late Brkng. Poster #16 (2008).
[2] Mastronarde, D. N., J. Struct. Biol. 120 (1997) 343-352.
[3] Winkler, H., Taylor, K.A., Ultramicroscopy, 106/3 (2006) 240-254.
[4] Dohnalkova, A., M.J. Marshall, W.R. Jarisch, J.K. Fredrickson, Proceedings of the Asia-Pacific Congress on Electron Tomography, Brisbane, AUS, (2009).
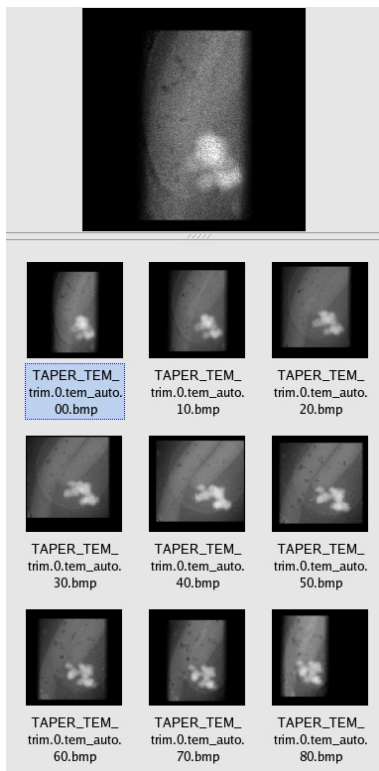
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1 Patent Pending

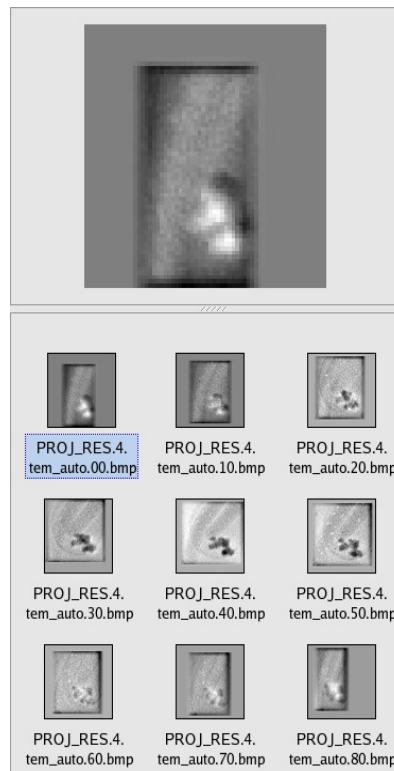Fig 1. Subset of nine original projections from (+/-) 60º (data from [4]).

Fig 2. Nine sample residuals from (+/-) 60º after alignment *without* contrast correction.
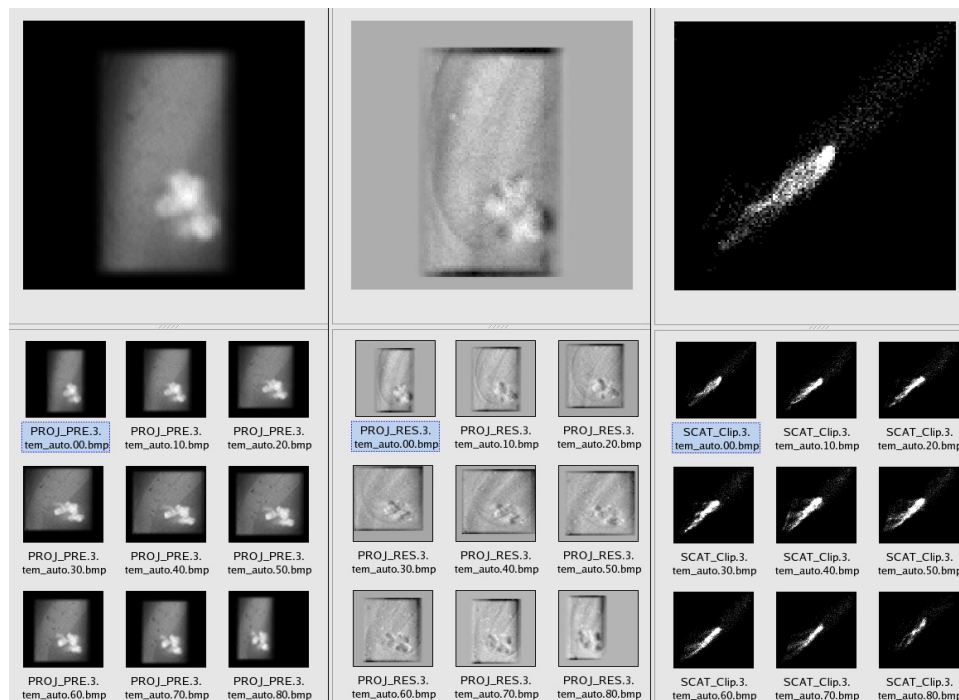

Fig. 3. Analysis of aligned projections: left – projection of HECT reconstruction; middle – HECT residuals with contrast correction; right – scatter plot of original data vs. prediction.