Current Issues in GENFIT

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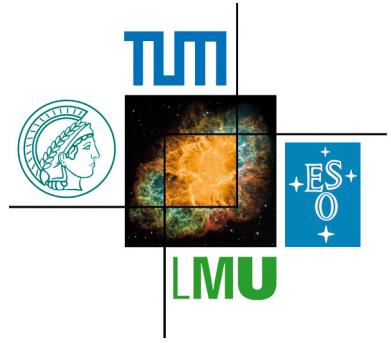

Topics

1. Precision issue in Jacobian calculation
2. Strong sensitivity of perigee covariances on quality of perigee determination

Quick Facts on Jacobians

At any point along a trajectory it is uniquely defined by five parameters (barring MS and other statistical modifications of the track):

- GENFIT RKTrackRep state 5D: $s = (q/p, u', v', u, v)$ defined on plane, u, v planar coordinates, u', v' direction cosines

The same trajectory at another point will be specified by a different set of parameters (linked by helix) $\tilde{s} = (q/\tilde{p}, \tilde{u}', \tilde{v}', \tilde{u}, \tilde{v})$.
The derivative of this mapping is the Jacobian matrix

- $J \equiv \frac{\partial(q/\tilde{p},\tilde{u}',\tilde{v}',\tilde{u},\tilde{v})}{\partial(q/p,u',v',u,v)}$

Rows and columns are chosen such that the chain rule works:

- If $s_f \xleftarrow{J_2} \tilde{s} \xleftarrow{J_1} s_i$ then $s_f \xleftarrow{J} s_i$ where $J = J_2 J_1$ (matrix multiplication)

The covariance matrix of the state develops by standard error propagation

- $C_f = J C_i J^T (+ \text{noise})$

Extrapolation in the RKTrackRep

GENFIT's Runge-Kutta extrapolator internally uses a 7D represenation

- $(x, y, z, a_x, a_y, a_z, q/p)$ where $|\boldsymbol{a}| = 1$.

Therefore, extrapolation has to involve two additional Jacobians, three in total:

1. convert 5D to 7D: J_{75}
2. extrapolation J (7×7) matrix
3. convert 7D to 5D: J_{57}

Here, the back-conversion takes place on a different plane, and thus is not the inverse operation.

- In the actual implemenation, this back-conversion is done at each extrapolation step to allow correct handling of noise.

What's Going Wrong?

Extrapolation goes from Si layer to Si layer in three steps (probably boundary between air volumes leads to third step, not yet investigated).

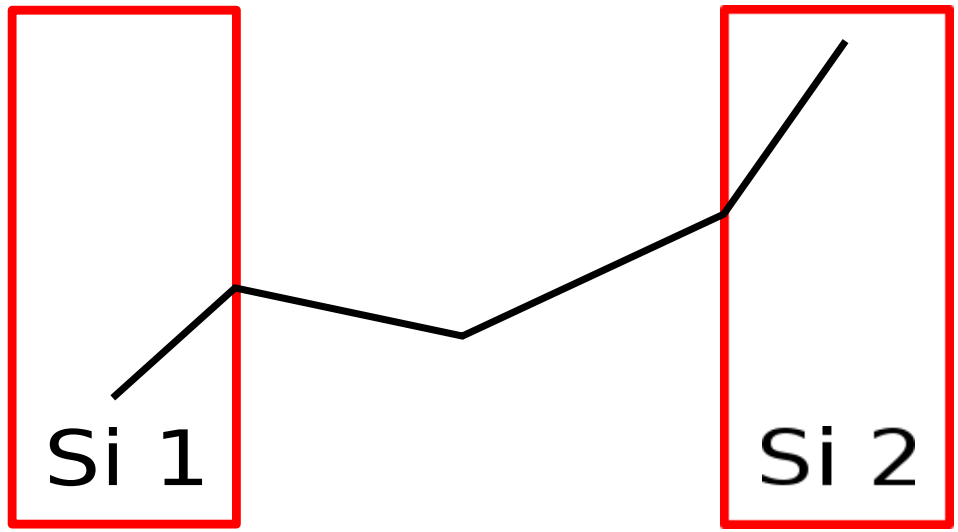

Figure : Sketch of three step extrapolation

The steps inside the silicone are very short, and here the Jacobians misbehave: in a homogeneous field diagonal elements in 5D for parallel planes should be unit. Deviations on 10^{-4} level. Tadeas found impact on alignment.

Status

Work done:

- checked implementations of matrix algebra that make use of known zeros in Jacobians
- checked calculation of Jacobians of 5D $\rightarrow$ 7D and back conversion
- checked handling of orientation WRT surface normal in 5D representation

No success yet, it appears the RK does something bad on very short steps

- I'm now working on understanding the implementation of the Jacobian calculation in the RK stepper. Hope to find the bug there. I already found an approximation, but I don't see how it can fail for small steps.

So far, I made some enhancements to the numerics in the code, but they have no significant impact.

Concerning Perigees

This item was discussed on the mailing list, I just want to make sure that we agree on priorities.
Problem definition:

- `GENFIT` steps very close to perigee, but not exactly
- conversion of covariance matrix to/from helix represenation appears to be extremely sensitive to distance from actual perigee

My proposed strategy:

- in `GENFIT`, after going close to the perigee with Runge-Kutta, solve helix equation (probably linearized) to find exact perigee.
- transport state and covariance there
- convert to helix representation

The question is whether this is less important than the Jacobian business. But probably the question is moot, now that the new MC production campaign started.

Thanks