Title

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ABSTRACT

A brief description of the vertex finding and track matching procedures used by the DAPR program is given.

Vertex searching is accomplished by finding in each view all clusters of tracks whose ends are near the common intersection point of their descriptive circles. These view-vertices are spatially matched to associate clusters in the three views.

Tracks of spatially matched clusters are compared to produce for each track in space the list of corresponding image tracks in each view. The algorithms used stress speed of decision. The comparison between views is a powerful tool used to clean up ambiguities unresolvable in individual views.

Experience in use has demonstrated the speed and validity of the procedures used. Some additional degree of sophistication in the decision logic gives great promise of achieving results fully as good as the most careful manual scanning procedures.

The following paper is a brief description of the vertex finding and track matching algorithms used by the DAPR system.

DATA

Fiducial measurements together with a list of track information blocks are input from the disk for each view of a triad. A track information block consists of a label, ionization information, and up to 18 average points. This list is called RTBL.

VERTEX SEARCH

The transformation from FSD coordinates into a standard lens coordinate system with the origin at the lens axis is computed from the fiducials for each view.

An auxiliary track list (TTBL) is generated. This consists of the first, middle, and the last point in the lens coordinate system together with the circle coefficients (a, b, r).

A preliminary vertex list (VWVTX) is constructed independently for each view as follows:

1. For each end of each track, a list (B1BUF) is formed consisting of the track identification (reference to RTBL and TTBL) and the coordinates of the end point $X_E Y_E$.
2. B1BUF is sorted in order of increasing X_E.
3. For each entry in B1BUF a rectangular zone is constructed about $X_E Y_E$. (see Fig. 1)
4. A list (B2BUF) is formed consisting of the current track together with each successive entry in B1BUF which has an endpoint within the zone.
5. A tentative vertex point is computed for the first pair of entries in B2BUF by intersecting the circles associated with the two tracks. If this point lies within 1000 μ of either endpoint, this pair of tracks together with all remaining entries in B2BUF whose circles pass within 100 μ of the tentative vertex point are entered into the preliminary vertex list (VWVTX.) An improved vertex point is computed by least squares, and the participating tracks are removed from B2BUF. This process continues until all pairs have been tried or all entries have been successfully deleted. Preliminary vertices which lie within 120 μ (weighted by their error ellipse) of previously established vertices are ignored.

When the VWVTX list has been completed for all three views, the entries are required to be spatially matched with an entry in at least one other view. A list, VTX, of all such spatially matched vertices is generated. When one view is missing, the vertex position is predicted from the other two views and an entry in the appropriate VWVTX list is made.

For all spatially matched view-vertices, a search of the entire track list is made to pick up any tracks missed in the initial search. Such tracks are usually due to unfollowed regions near the vertex or poor vertex point determination due to inclusion of interloper tracks. If any new tracks are found the vertex point is re-computed together with its error ellipse. Each participating track's circle is then required to pass within 500 microns of the vertex point (weighted by the error). If this process removes all of the tracks from a view-vertex (including the one in which no tracks were picked up by the exhaustive search, for a predicted vertex), the corresponding VTX entry is deleted.

The VTX list thus contains all the real vertices together with a few fake vertices due to view-verticies whose spatial position lies within the chamber, but whose tracks are unrelated.

TRACK MATCH

For simplicity in this discussion, we make two assumptions. First, that the camera lenses are pinholes, and second that the index of refraction of air glass and hydrogen are all equal. A more accurate approximation is used within the actual program.

Consider a point P on the film in one camera of a stereo pair. (See figure 2) If the point in space which produced P is inside the chamber, it must lie on the line segment AB in space. Therefore its image on the second film must lie on the projection of AB to the second film A'B'. The line segment A'B' has two useful properties.

1. It is parallel to the stereo axis.

2. The distance between P and A', and the distance between P and B' are constant for all choices of P.

Because of these properties, it is extremely simple to produce A' and B' given P. Namely if $P = (X, Y)$ then $A' = (X + \Delta X_1, Y + \Delta Y_1)$ and $B' = (X + \Delta X_2, Y + \Delta Y_2)$ where ΔX_1, ΔY_1, ΔX_2, ΔY_2 can be determined once and for all for a given chamber. The line segment A' B' is called the "slit" for P.

Track matching operates on one spatially matched vertex at a time. Tracks which have "followed through" the vertex (i.e. have the vertex point interior) are divided into two separate tracks and the circle coefficients for the two halves are computed.

A primary view is selected. For the 72" hydrogen chamber this is view 2 since tracks in view 2 are guaranteed to make at least a 45° angle with the stereo axis for one of the other two views.

TWO VIEW MATCH

Each track in the primary view is processed as follows:

A secondary view is selected for optimum stereo reconstruction and slits corresponding to the first (nearest the vertex), middle, and last point on the primary track are computed.

Each track in the secondary view is screened by the following tests in order. When a test fails, the program immediately skips to the next track.

<u>Sign of Curvature</u>: Does the sign of curvature in the secondary view match the sign of curvature in the primary view? If either track is straight (sagitta less than 20μ), the test is bypassed.

<u>Stereo Axis</u>: Is the endpoint (end away from the vertex) in the secondary view on the same side of the stereo axis (translated to the vertex) as the endpoint in the primary view?

<u>Track Length</u>: Is the ratio of the length of track in the primary view to the length of track in the secondary view less than 4 or greater than 1/4?

<u>Endpoint Slit</u>: Does the track in the secondary view pass through the endpoint slit? This test is very fast due to the availability of the circle coefficients. One end of the slit must be inside the circle and the other outside. If this test is passed, the points corresponding to the endpoint in the primary view are computed for the secondary and tertiary views.

<u>Mid Point Slit</u>: This test is the same as the previous test but uses the midpoint slit. Again the corresponding points are computed if the test is passed.

<u>Helix</u>: The point in the secondary view corresponding to the first point in the primary view is now computed, as well as the separations of the two tracks at the beginning, middle and endpoints. If the two tracks represent the same helix in space, these separations will vary linearly with arc length. Thus the midpoint separation can be predicted from the beginning point separation, the end point separation and the arc length to the midpoint in the primary view. The predicted midpoint separation is required to be within 250μ of the observed midpoint separation.

The helix test is the most demanding test applied in this series. Approximately half of the secondary track candidates which survive the previous tests are rejected by this test. Only about 1% of the secondary view, non-beam, tracks which survive the helix test are false matches.

THREE VIEW MATCH

Tracks which survive all the above tests are listed together with the corresponding points in the secondary and tertiary views. If no two-view match was successful the program will repeat the above procedure, using the remaining view as the secondary view, provided that stereo reconstruction is possible. If at least one two-view match was successful, the program proceeds to the track list in the tertiary view. Each track in the tertiary track list is then screened through the following tests:

Sign of Curvature: Same as for two view matching.

Stereo Axis: Same as for two view matching.

Endpoint Proximity: Does the predicted endpoint in the tertiary view lie within 250 microns of the candidate track in the tertiary view? This test is also quite fast due to the availability of the circle coefficients. The approximation $d = 1/2 \left[\frac{(x-a)^2 + (y-b)^2}{r} - r \right]$ is used.

Midpoint Proximity: Same as the previous test using the predicted midpoint.

Track Length: Same as for two-view matching.

If no three-view match was successful, the list of two-view matches is retained. Otherwise, only the three-view matches are kept.

The entire procedure of two and three-view matching is repeated for each track in the primary view.

When the list of tracks in the primary view has been exhausted, a final two-view match between the secondary and tertiary view track lists is performed avoiding all tracks which have been previously used in three-view matches.

CLEAN UP

The list of matched tracks is now examined for ambiguities. The first step is to discard any two-view match which shares a common track-view with a three-view match.

All the three-view, unique, entries (matches which have no track-view in common with any other list entry) are then removed from the list and prepared for output. This usually removes all of the non-beam tracks.

The remaining entries are now grouped into sets of related matches. For each set an attempt is made to select the correct entries on the basis of agreement in track length between views. If selection is possible the chosen entries are removed and prepared for output.

Output consists of a matrix in which each track in space is associated with its track-view images. The dip angle, azimuthal angle and radius in space are also computed.

OPERATING EXPERIENCE

Experience with this process in operation has suggested further refinements to be added, especially to the cleanup operations. These should result in fewer ambiguities, and in the loss of fewer events because of narrow margins of decision against one track-view. However, this process as it stands yields unambiguous, completely matched sets of tracks for most events in the sample studied. Greater sophistication is needed primarily to deal with the cases of obscured, kinked or otherwise garbled track data.

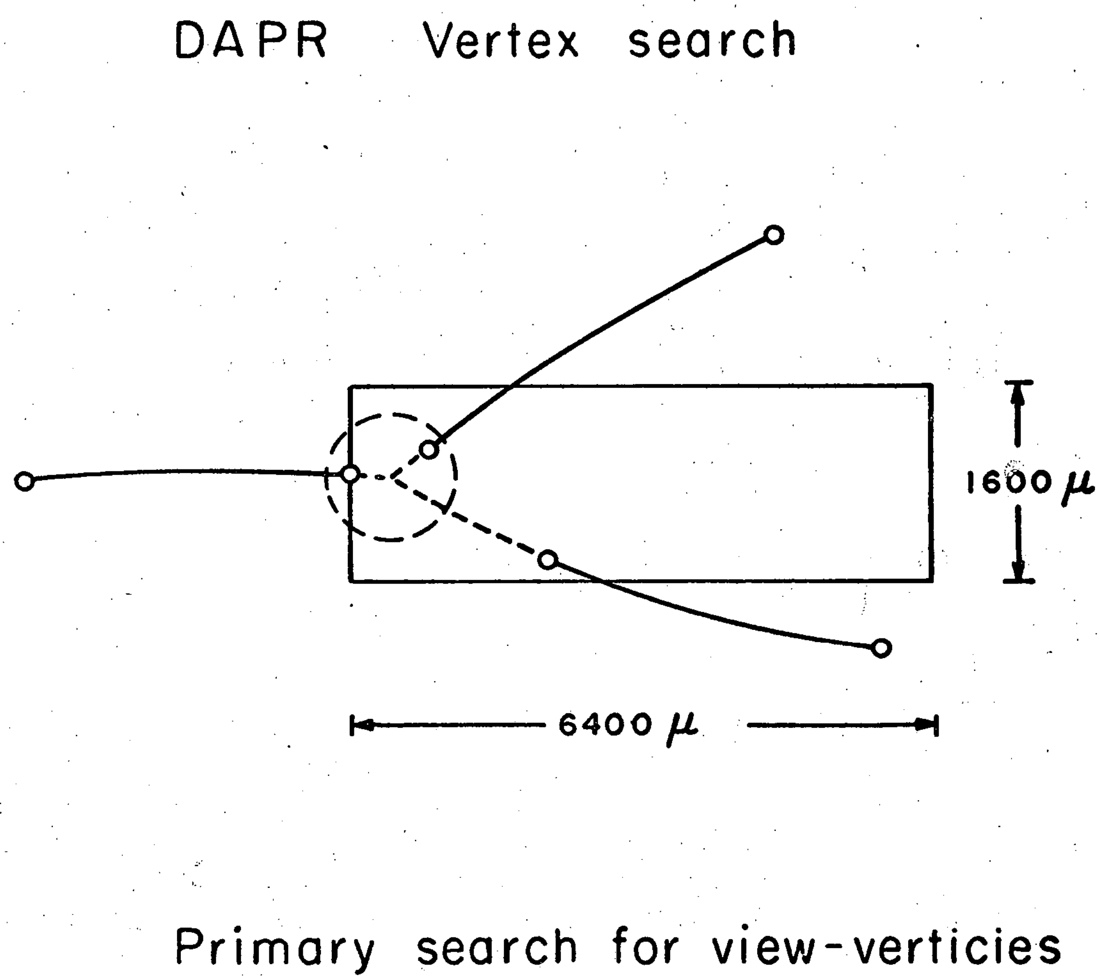

Fig. 1. XBL6810-6904

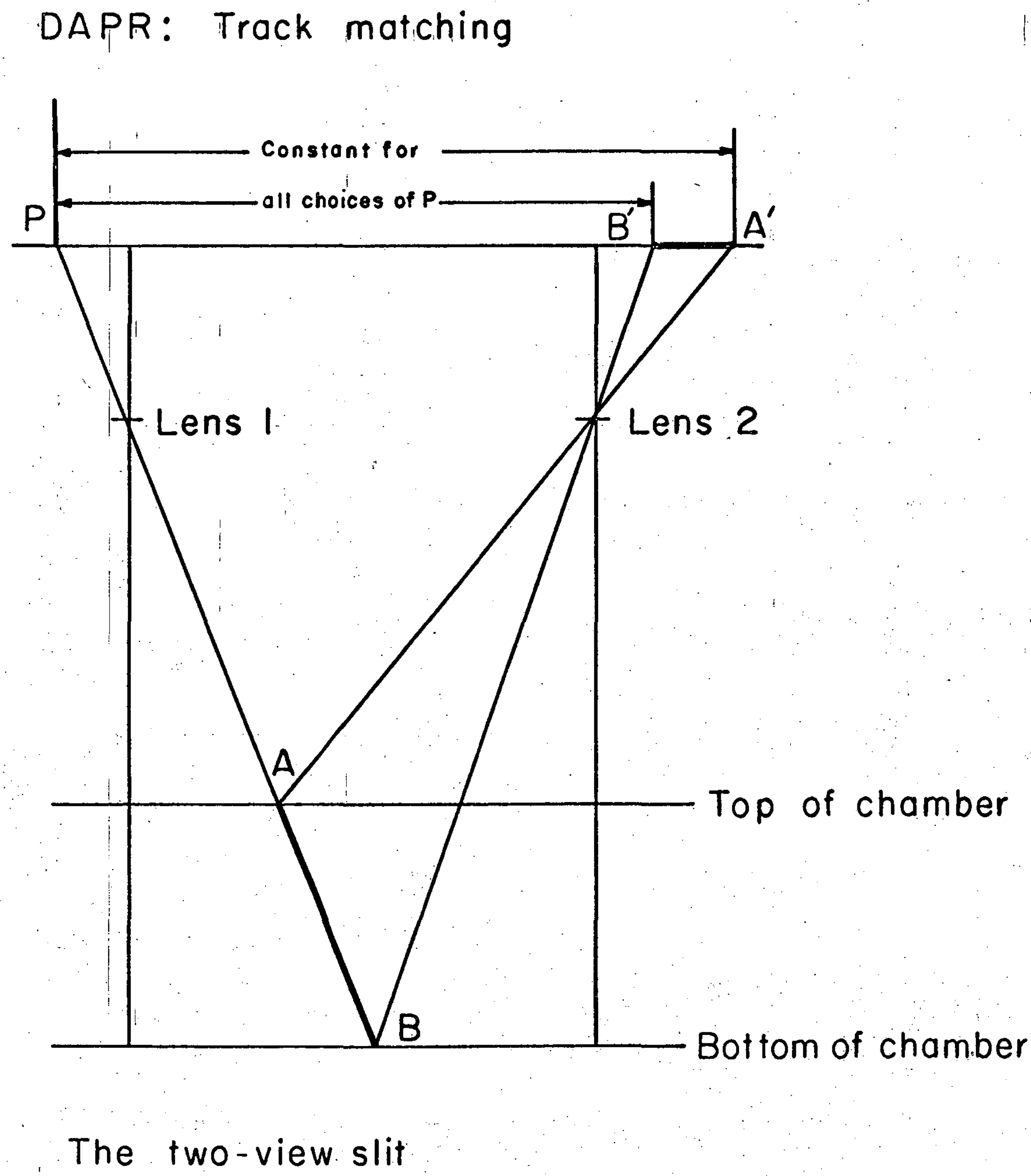

Fig. 2. XBL6810 - 6903