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SARA2 Interpolation and Extrapolation schemes

SARA2 software contains support for both 2D cubic B-spline interpolation as well as 3D cubic B-spline interpolation. In addition, for extrapolation purposes, a general n^{-th} order polynomial fitting routine is implemented following a singular value decomposition algorithm presented in [1]. A 4^{th} order polynomial fit is used by default for data extrapolation, but a linear-logarithmic fitting function can be selected as an option. The polynomial fitting procedures have been tested by comparing the fitting coefficients generated by the SARA2 procedures with those obtained using the polynomial fit functions of Microsoft Excel when applied to the same test input data.

Interpolation of 2D area scan
The 2D cubic B-spline interpolation is used after the initial area scan at fixed distance from the phantom shell wall. The initial scan data are collected with approx. 10mm spatial resolution and spline interpolation is used to find the location of the local maximum to within a 1mm resolution for subsequent 3D scanning.

Extrapolation of 3D scan
For the 3D scan, data are collected on a spatially regular 3D grid having (by default) 6.4 mm steps in the lateral dimensions and 3.5 mm steps in the depth direction (away from the source). SARA2 enables full control over the selection of alternative step sizes in all directions.

The digitised shape of the head is available to the SARA2 software, which decides which points in the 3D array are sufficiently well within the shell wall to be 'visited' by the SAR probe. After the data collection, the data are extrapolated in the depth direction to assign values to points in the 3D array closer to the shell wall. A notional extrapolation value is also assigned to the first point outside the shell wall so that subsequent interpolation schemes will be applicable right up to the shell wall boundary.

Interpolation of 3D scan and volume averaging
There are two procedures implemented for this. The first scheme is that which has been used in previous versions of the SARA software. The second is a new implementation adapting the surface of the 'cube' to conform with the curved inner surface of the phantom (Appendix C.2.2.1 in EN 50361).

Original scheme
This evaluates a volume average centred on each point of the scanned 3D array. Around each point a finer grid is defined with a side corresponding either to a 1g averaging volume or a 10g volume and a value at each point of this finer grid is interpolated using a least-squares inverse distance average of

the contribution from all the nearest grid points in each direction. Points lying outside the shell are ignored. The values from the finer grid within the shell are averaged to provide the result.

Conformal scheme
For each row of data in the depth direction, the data are extrapolated and interpolated to less than 1mm spacing and average values are calculated from the phantom surface for the row of data over distances corresponding to the requisite depth for 10g and 1g cubes. This results in two 2D arrays of data which are then cubic B-spline interpolated to sub mm lateral resolution. A search routine then moves an averaging square around through the 2D array and records the maximum value of the corresponding 1g and 10g volume averages. For the definition of the surface in this procedure, the digitised position of the headshell surface is used for measurement in head-shaped phantoms. For measurements in rectangular, box phantoms, the distance between the phantom wall and the closest set of gridded data points is entered into the software.

Related measurement parameters defined in EN 50361

dbe - the distance between the surface and the closest measurement point used for the cube averaging process
For measurements in box-shaped phantoms, this distance is under the control of the user. The effective distance must be greater than 2.5mm as this is the tip-sensor distance and to avoid interface proximity effects, it should be at least 5mm. A value of 6 or 8mm is recommended.

For automated measurements inside the head, the distance cannot be less than 2.5mm, which is the radius of the probe tip and to avoid interface proximity effects, a minimum clearance distance of x mm is retained. The actual value of dbe will vary from point to point depending upon how the spatially-regular 3D grid points fit within the shell. The greatest separation is when a grid point is just not visited due to the probe tip dimensions. In this case the distance could be as large as the step-size plus the minimum clearance distance (i.e with x=5 and a step size of 3.5, **dbe** will be between 3.5 and 8.5mm).

dstep - the separation between the first and second closest points, assuming that the boundary effect at that location is negligible
The default step size used is 3.5mm, but this is under user-control. The compromise is with time of scan, so it is not practical to make it much smaller or scan times become long and power-drop influences become larger.

dss - the uncertainty to the SAR measurements through the accuracy and repeatability of positioning
The positioning system specification for the repeatability of the positioning is +/- 0.04mm.

dph - the shape and the thickness of the phantom shell
The phantom shell is made by an industrial moulding process from the CAD files of the SAM shape, with both internal and external moulds. For the upright phantoms, the

external shape is subsequently digitised on a Mitutoyo CMM machine (Euro C574) to a precision of 0.001mm. Wall thickness measurements made non-destructively with an ultrasonic sensor indicate that the shell thickness away from the ear is 2.0 +/- 0.1mm. This has been confirmed by mechanical measurements on available cut surfaces of the phantom shells.

dmis - the alignment between position of the probe and the phantom

For the upright phantom, the alignment is based upon registration of the rotation axis of the phantom on its 253mm diameter baseplate bearing and the position of the probe axis when commanded to go to the axial position. A laser alignment tool is provided (procedure detailed elsewhere). This enables the registration of the phantom axis to be assured to within approx. 0.2mm. This alignment is done with reference to the actual probe tip after installation and probe alignment. The rotational positioning of the phantom is variable – offering advantages for special studies, but locating pins ensure accurate repositioning at the principal positions (LH and RH ears).

Reference:

[1] “Numerical Recipes in C”, WH Press, SA Teukolsky, WT Vetterling and BR Flannery, Cambridge University Press, Second Edition, 1992.