Abstract – ***Multidimensional Visualization and its Applications***

With **Parallel Coordinates** the perceptual barrier imposed by our 3-dimensional habitation is breached enabling the unambiguous visualization of multidimensional problems and multivariate relations. For $\mathbb{R}^N$ points are mapped into planar polygonal lines (see representation of vertices in Fig. 3) and hypersurfaces into $(N-1)$ distinct planar regions. The methodology is developed intuitively from its foundations to recent result like the visualization of proximity for families of "close" lines & hyperplanes; a central problem in many applications. Properties of hypersurfaces are detected from their representation. Convexity in *any dimension* or non-convex features like bumps, dimples, coiling, non-orientability can be recognized from one orientation, unlike standard 3D surface representations (see Figs. $3 \rightarrow 5$). Concepts and applications are illustrated interactively.

The parallel coordinates methodology has been applied to collision avoidance algorithms for air traffic control (3 USA patents), computer vision (USA patent), data mining (USA patent) for data exploration (Fig. 1) and automatic classification (Fig. 2), optimization, process control and elsewhere.

KEYWORDS: Multidimensional Visualization, Parallel Coordinates, Visual & Automatic Data Mining, Multidimensional Problems

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"EYE-CANDY"

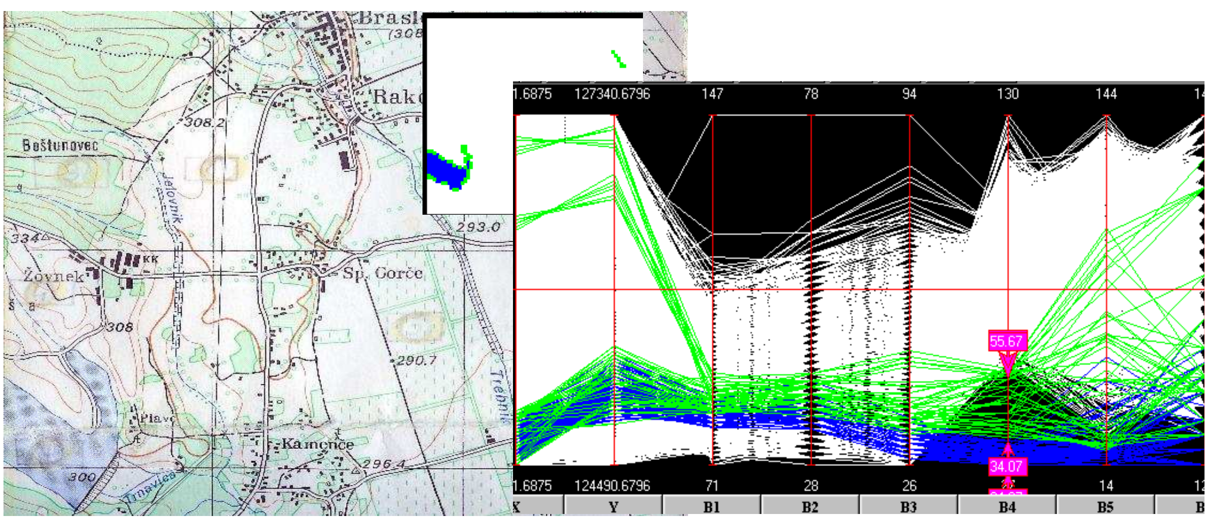

Figure 1: Exploratory Data Analysis: ground emissions measured by satellite on a region of Slovenia (left) are displayed on the right. Water and lake's edge (middle) are discovered as indicated.

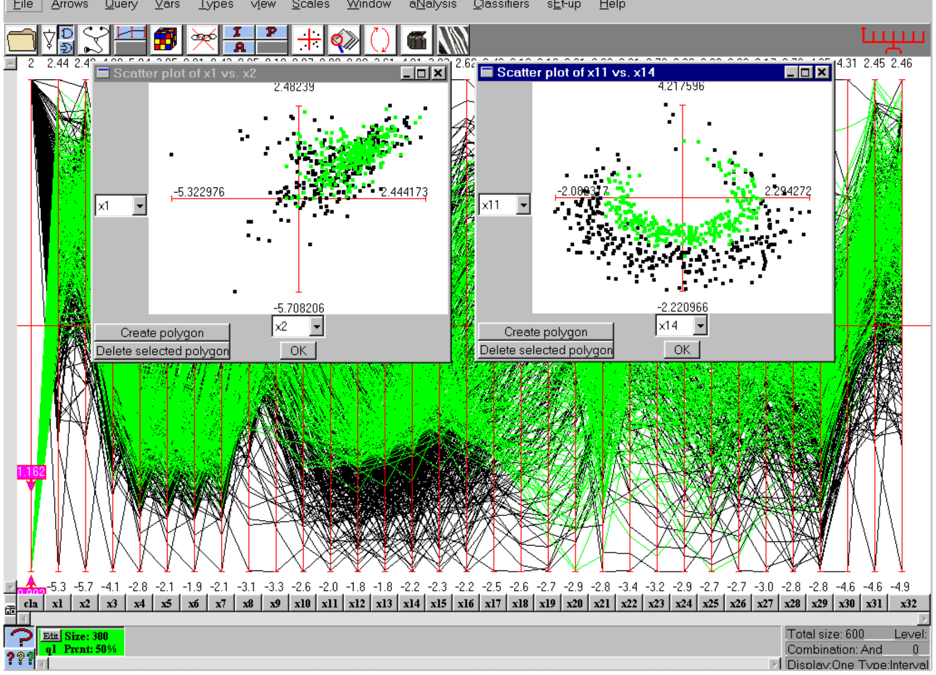

Figure 2: In the background is a dataset with 32 variables and 2 categories. On the left is the plot of the first two variables and on right the best two variables after classification.

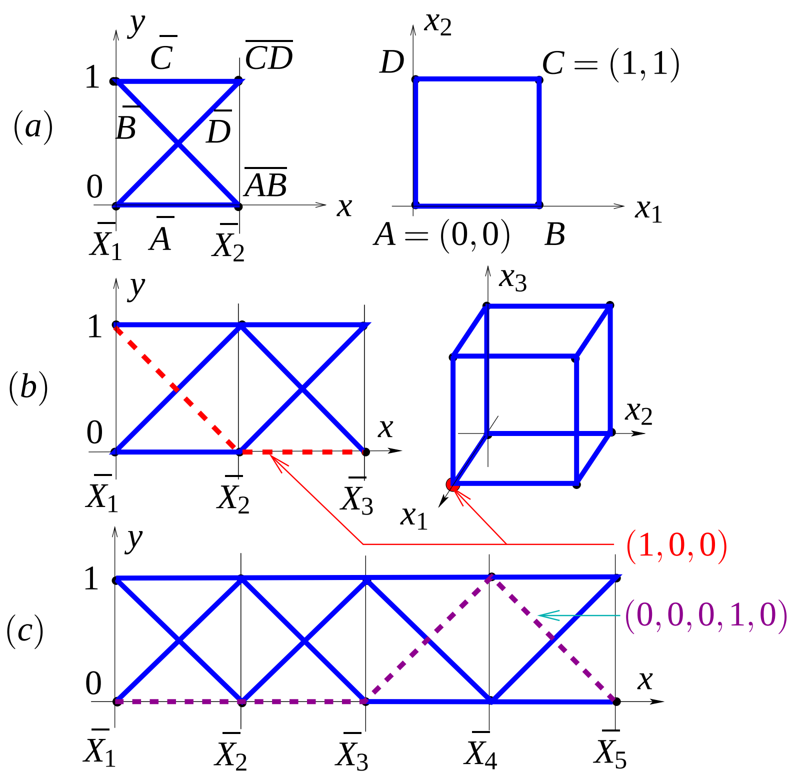

Figure 3: Square, cube and hypercube in 5-D. Vertices are represented by polygonal lines.

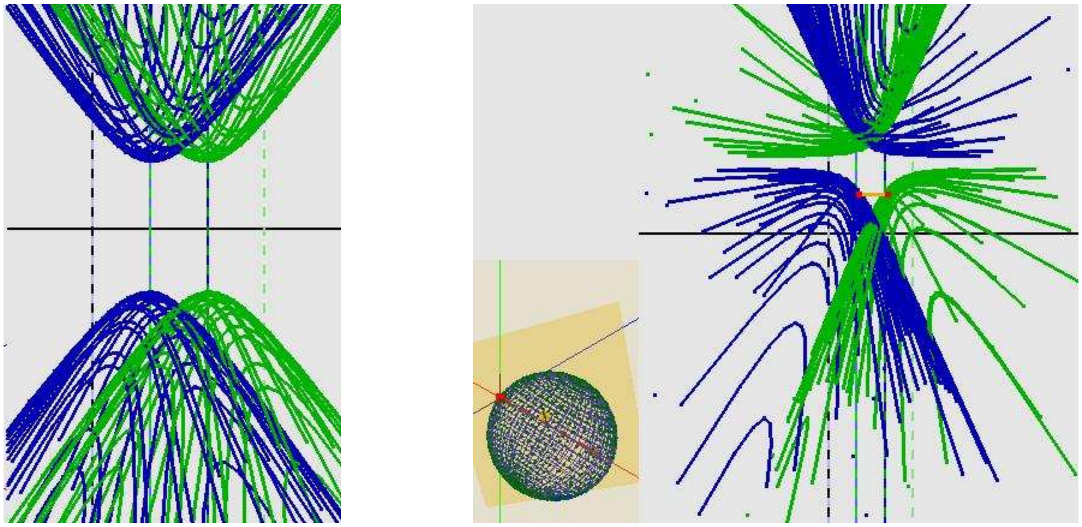

Figure 4: Representation of a 3-D sphere centered at the origin (left) and after a translation along the x_1 axis (right) causing the two hyperbolas to rotate in opposite directions; this is an example of *rotation* $\leftrightarrow$ *translation* duality. In N-dimensions a sphere is represented by $N-1$ such hyperbolic regions — pattern repeats as for hypercube above.

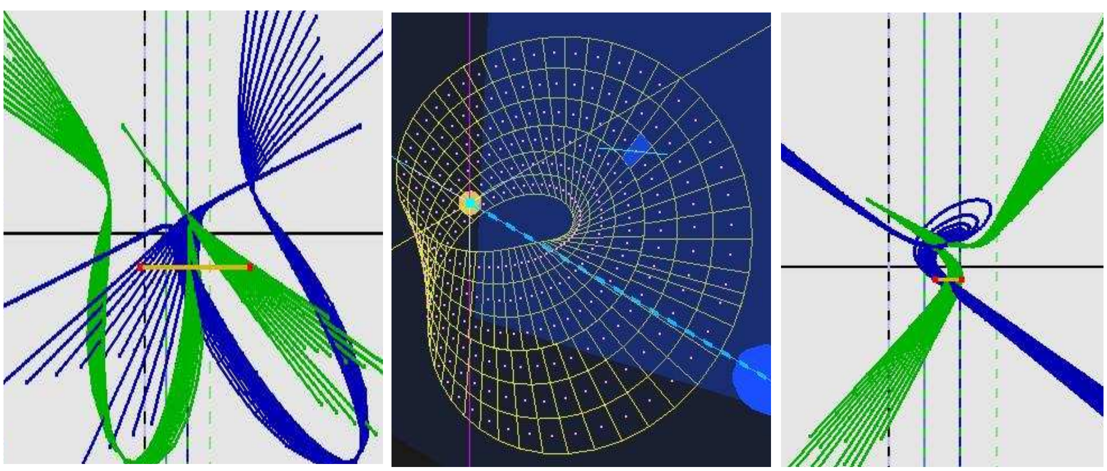

Figure 5: Möbius strip and its representation for two orientations. The interwoven cusps correspond to an "inflection-point" in 3-D.