A Comparison of Euclidean and Brain Surface Cortico-cortical Distance Measures

J. Daniel Turner, Bharat Joshi, Ashish Panday, Reshma Munbodh, Hitten P. Zaveri

INTRACRANIAL EEG (icEEG) inter-contact distance, which is important for measurements of brain relationship and estimates of signal transmission time, is commonly estimated as the Euclidian distance between the centers of two icEEG contacts. Though computation of Euclidean distance is less expensive, it can considerably underestimate the distance between two icEEG electrode contacts, which can adversely affect estimates of brain relationship and time-delay. In this paper we propose a more accurate method to estimate the distance between icEEG contacts.

Intracranial EEG electrode contacts placed in 22 adult patients being monitored for epilepsy surgery were accurately located from post-implant CT and co-registered to a pre-implant MR scan and the MR of a standard brain. The MR images were rendered as a 3D surface mesh. The intracranial electrodes used in this study are either strips with 4 to 12 contacts or grids ranging in size from 4 by 6 contacts to 8 by 8 contacts. Contacts are disks with diameter 4 mm and with 5 mm or 10 mm center-to-center spacing. The Euclidean distances between all possible pairs of electrode contacts ranged from 5 mm to 181 mm. Cortico-cortical distance along the brain surface was calculated using a variant of Dijkstra's algorithm, a common shortest-path algorithm. As shown in Fig 1, the surface distance estimates were considerably greater than the Euclidean estimates.

The distance pairs were separated into groups of 10 mm increments based on the Euclidean distance. In the majority of instances, the surface distances were approximately 20% to 50% longer, with a tendency toward 30% (Fig 2.) The largest individual discrepancies between Euclidean and surface distances, some exceeding a factor of 10, were observed for Euclidean distances less than 20 mm. These extreme cases are very rare events. If a patient has 200 contact pairs with a Euclidean distance less than 10 mm, no more than 5 would have a surface distance that is greater than 4 times the length of the Euclidean distance. More than 150 of those pairs would have a surface distance that is less than 50% greater than the Euclidean distance.

We are currently investigating the possibility of determining general guidelines for approximating surface distances from Euclidean measurements and improving computational efficiency to approximate surface distances. We are also evaluating functional measures, such as spike propagation, as functions of Euclidean and surface distances to further demonstrate the importance of using surface distances for functional measures.

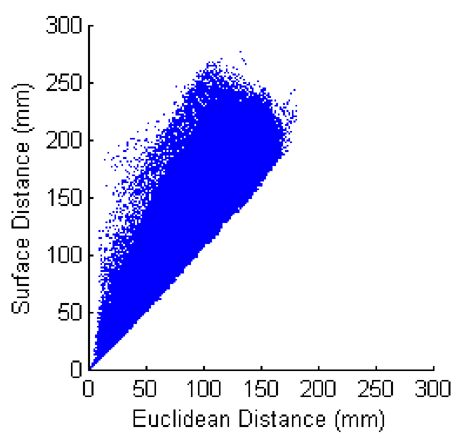

Figure 1: Surface Distance vs. Euclidean Distance
Of the 424,870 distance pairs studied, the majority fall into a wedge between y=1.2x and y=1.5x. Relatively few instances lie above this range, and the most extreme instances are less than 20 mm.

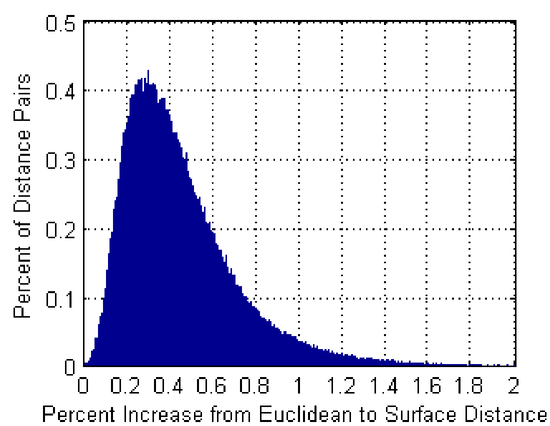

Figure 2: Cohort Histogram for Euclidean Distances
This figure shows the percent increase from the Euclidean distance to the surface distance. 2257 distance pairs with a percent increase over 200% (0.53% of total data) have been excluded for clarity.

J. Daniel Turner, Bharat Joshi, and Ashish Panday are with the Department of Electrical and Computer Engineering, University of North Carolina, Charlotte, NC 28223 USA. (phone: 704-687-8407; email: jturn101@uncc.edu)
Reshma Munbodh is with the Department of Radiation Oncology, University of Pennsylvania, Philadelphia, PA, 19104 USA
Hitten P. Zaveri is with the Department of Neurology, Yale University, New Haven, CT, 06520