Visualization of Damage in Laminated Composite Structures Using GIS

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Introduction:

The Finite Element Analysis (FEA) is a popular analytical tool for damage analysis of nonlinear structural systems. In most cases, the post-processing of data shows displays relating to stresses, strains, thermal gradients, pressure gradients, electromagnetic pulses, etc. Laminated composites (see Figure 1) are increasingly being used as structural materials in the automotive, aerospace and alternative energy industries. There is therefore a requirement for the simulation tools that are employed in those industries to provide capabilities for modeling laminated composite materials efficiently and effectively.

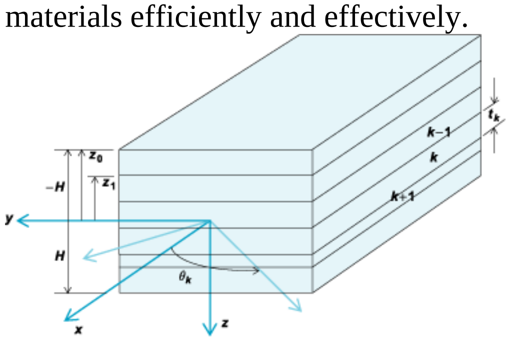

Figure 1

Laminated composites present particular challenges for the Finite Element analyst: the simulation model in FEA needs to be constructed to include information on layup and orientations; the material constitutive models including anisotropy and, possibly, complex modes of damage and failure; and specific responses such as delamination may need to be taken into account. This paper proposes to create a layered system of visualizing multiple measures of damage using the spatial properties embedded within a Geographic Information Science, GIS [1].

Laminated and Layered Systems:

A laminated composite and a layered system have a common spatial feature. GIS transforms and displays spatial data from the real world for a particular set of purposes [2, 3]. Additionally, GIS can be described as an information system that is designed to work with data referenced by spatial or geographic coordinates. Hence, GIS is both a database system with specific capabilities for spatially-referenced data, and a set of operations for working with the data [4]. GIS allows us to manipulate and display geographical knowledge in new and explicitly ways in 2D or 3D. The most important point is that GIS makes connections between activities based on geographic proximity. Looking at data geographically can often suggest new insights and explanations. These connections are often unrecognized without GIS, but can be vital to understand and manage activities and resources. Therefore, GIS is an "enabling technology" because of the potential it offers for the wide variety of disciplines which must deal with spatial data. Each related field provides some of the techniques which make up GIS. Many of these related fields emphasize data collection. GIS brings them together by emphasizing integration, analysis, modeling, monitoring and even prediction capability. As the integrating field, GIS often claims to be the science of spatial information. This paper discusses two scenarios whereby GIS can be applied at different scales. At an earth surface example, the paper discusses the scenario in which GIS may be used to monitor and predict possible damage due to a crack caused by an earthquake tremor on physical and manmade structures at a city size level. A main aspect of this paper is represented in the second scenario in which GIS is used to monitor and predict the impact of possible damage in composite laminated structures. An example is the damage monitoring of elements of an airplane wing. In both cases, the paper demonstrates the power of GIS in collecting geographically referenced data, manipulating them, organizing and modeling them to be visualized in a way an engineer can get an insight of a possible damage and the impact that damage can cause to neighboring features or layers. The design goal is continuous damage assessment.

Examples:

In Figures 2 and 3, a vector-based overlay operation combines geometries and attributes from different layers to create the output (left). A raster data operation with multiple rasters can take advantage of the fixed cell locations (on the right). For example a local average can easily be computed by dividing the sum of 2, 3 and 4 (9) by 3 according to Chang [6].

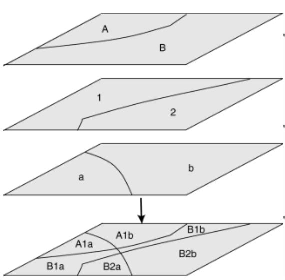

Figure 2

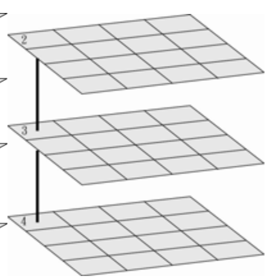

Figure 3

Figure 4 demonstrates a composite material with five laminates that contain two cracks in the second and fourth laminates from the bottom. Using spatial coordinate systems in GIS we can visualize these cracks, not just in three-dimensional form, but also in two-dimensional form as well. In Figure 5, three point features on the earth surface with their respective projected coordinates, (a) on a vector data format and (b) on raster data format. The model example shown in Figure 5 could represent a study of impact of an earthquake created crack on road network and river network systems in a given city [5].

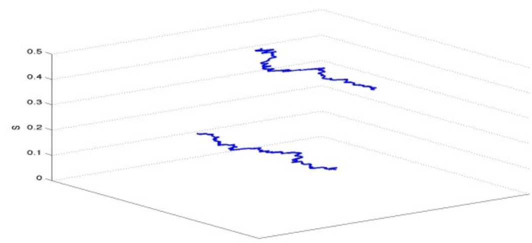

Figure 4

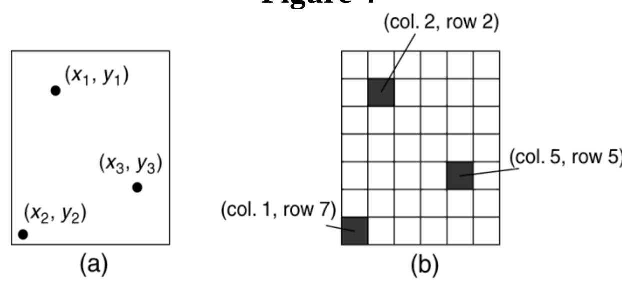

Figure 5

In this hypothetical example (Figures 2, 3), the left topmost spatial layer represents two zip codes A and B of the city. The second layer provides a linear river system layer crossing and dividing the city into two sections 1 and 2. The third layer represents the GPS- tracked linear crack caused by the earthquake and dividing the city into two parts: a and b. The first condition that can enable informed analysis on these GIS layers is that they should be in one projection system. When you overlay all layers you should have a complete map showing on the left lowermost layer. It is possible to convert the vector linear features to raster data for some additional analysis if need be by using available GIS analytical modules.

References:

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