In this paper I will survey the advantages of hexagon-based location systems that seamlessly tile the globe. (Sahr et al., 2003): multi-resolution, hierarchically indexed research in hexagon-based location coding has culminated in increase (Middleton 2005). At the same time, decades of on-going for over 40 years, and has recently seen a sharp increase. Hexagonal image processing and pattern recognition has been built on substrates of square lattices. The common standards have long been raster grids of square pixels and vector coordinates consisting of 2- or 3-tuples of floating point values.

Yet if the goal is optimal representational and algorithmic efficiency and superior semantic expressiveness, then data structures based on squares are likely not the best choice. There is a substantial body of research that indicates that representations based on hexagonal lattices are superior, and such research has arrived at this conclusion consistently across a number of research areas that directly apply to geospatial systems, such as photogrammetry, image processing, and geospatial location coding. Research in hexagonal image processing and pattern recognition has been on-going for over 40 years, and has recently seen a sharp increase (Middleton 2005). At the same time, decades of research in hexagon-based location coding has culminated in the development of hexagonal discrete global grid systems (Sahr et al., 2003): multi-resolution, hierarchically indexed location systems that seamlessly tile the globe.

In this paper I will survey the advantages of hexagon-based raster and vector data structures, as well as those factors that have so far inhibited more widespread adoption of hexagon-based representations for geospatial applications.

ABSTRACT:
Advanced geospatial applications often involve complex computing operations performed under sometimes severe resource constraints. These applications primarily rely on traditional raster and vector data structures based on square lattices. But there is a significant body of research that indicates that data structures based on hexagonal lattices may be a superior alternative for efficient representation and processing of raster and vector data in high performance applications. The advantages of hexagonal rasters for image processing are discussed, and hexagonal discrete global grid systems for location coding are introduced. The combination provides an efficient, unified approach to location representation and processing in geospatial systems.

1. MOTIVATION
Advanced geospatial applications, such as mobile mapping, often perform complex spatial operations on potentially large data sets, with strict controls on the accuracy of internal location representations, and in computing environments that may be severely constrained by resource and size limitations. These systems therefore often place a premium on representational and algorithmic efficiency, and are in a constant state of improvement as more efficient representations and algorithms become available. Among the most fundamental data structures are those used for the representation and storage of raster image data and vector geospatial location data. Because they are so pervasive, even small improvements in efficiency or representational accuracy in these data structures can result in substantial performance increases in an overall system.

Data structures for the representation and storage of raster and vector data in geospatial applications have traditionally been built on substrates of square lattices. The common standards have long been raster grids of square pixels and vector coordinates consisting of 2- or 3-tuples of floating point values.

Yet if the goal is optimal representational and algorithmic efficiency and superior semantic expressiveness, then data structures based on squares are likely not the best choice. There is a substantial body of research that indicates that representations based on hexagonal lattices are superior, and such research has arrived at this conclusion consistently across a number of research areas that directly apply to geospatial systems, such as photogrammetry, image processing, and geospatial location coding. Research in hexagonal image processing and pattern recognition has been on-going for over 40 years, and has recently seen a sharp increase (Middleton 2005). At the same time, decades of research in hexagon-based location coding has culminated in the development of hexagonal discrete global grid systems (Sahr et al., 2003): multi-resolution, hierarchically indexed location systems that seamlessly tile the globe.

In this paper I will survey the advantages of hexagon-based raster and vector data structures, as well as those factors that have so far inhibited more widespread adoption of hexagon-based representations for geospatial applications.

2. HEXAGONAL IMAGE PROCESSING
As a basis for photogrammetry and general image processing, it is not an exaggeration to state that raster grids consisting of hexagonal pixels, arranged in a hexagonal topology, are superior to those based on square pixels of equivalent frequency under virtually every efficiency and geometric metric. Hexagon rasters are 13.4% more efficient at sampling circularly bandlimited signals (Petersen & Middleton, 1962), and processing algorithms on hexagon rasters are 25-50% more efficient (Mersereau, 1979). Staunton (1989) implemented a set of edge detection operators on a hexagonal raster and realized over 40% better performance compared to equivalent operators on square grids.

These efficiencies are closely tied to the unique geometric attributes of a hexagonal lattice. Hexagons have the highest symmetry and are the most circular of all regular polygons that tile the plane (Yale, 1968). Davies (1984) noted that operators defined on square rasters may be dominated by preferred horizontal and vertical directions, leading to anisotropy in the operators' spectral properties, and argued instead for isotropic hexagon raster operators that exhibit "circularity" (see also Coleman et al., 2004; Scotney & Coleman, 2007). Hexagon lattices have uniform and unambiguous connectivity, with each pixel having six neighbors with which it shares an edge, and whose centers are equidistant from its center. In contrast, a pixel in a square lattice has two types of neighbors: four pixels with which it shares an edge, and four pixels with which it shares a vertex, and the centers of the two types of neighbors are different distances from the central pixel. This fact alone leads to semantic paradoxes when dealing with boundaries on square lattices (Rosenfeld, 1970). The increased number of pixels in n-order neighborhoods on a hexagon raster allows for greater angular resolution (Golay, 1969). These neighborhoods are more circular than corresponding n-order neighborhoods on a square raster, making the discrete distance metric on a...