ABSTRACT

A topographic sheet is a scale-governed map that neatly organizes various morphological features associated with a geographical terrain as overlapping layers represented with distinctive color codes for facilitating visual interpretation. Some of the important morphological features represented in a topographic sheet include river networks, contour lines, lakes, transportation networks, and many more.

A river network is a well-organized, hierarchical natural arrangement of stream segments, tributaries, and confluences extending from the headstream towards medium streams, eventually joining the main streams. The structure of the river network is governed by the geographical landscaping of the terrain. Streams in the river network may be attributed to stream order, stream number, bifurcation ratio, weighted mean bifurcation ratio, stream length, mean stream length, length ratio, weighted mean length ratio, area coverage, carriage capacity, coordinate trails, and length of the mainstream.

A topographic sheet embeds annotations that concern multi-faced information pertaining to morphological features, elevating its understanding. The elevation value and names of the prominent features are examples of the same. Localization and recognition of such annotations would greatly help in operations such as 3-D projection and tracking of morphological features.

The topographic sheets are created and released by the surveying agencies at different scales for effective management of content. Scale adversely correlates with detailedness, i.e., the greater the scale, the lesser will be the detailedness, and vice versa. To elevate the quality of information contained by the feature set, the initiative should

either rely on maps with a smaller scale of representation or design knowledgeable, trained computer programs for generating new features based on the available information in the feature set. Furthermore, the contribution of these features to the morphological structure of the terrain may be understood only when these features are projected in the z-plane.

Morphological analysis of the identifiable features calls for their efficient extraction into distinct layers known as vectors. This challenge in the domain of geographic information system-based applications is referred to as Digitization. The act of digitization can be performed either manually or by deploying semiautomatic or completely automatic techniques. In the traditional manual approach, the digitizer picks the coordinates to digitize the feature of interest into a vector layer. A semi-automatic computer-aided process may also be used for digitization, wherein the digitizer makes use of computational tools for selecting the feature of interest into distinct layers. Both of these techniques mandate human intervention and are labor-intensive, extremely time-consuming, and expensive. Moreover, the results obtained lack confidence and are greatly subjected to the opinion and experience of the digitizer. Inaccurate digitization will not only influence the morphological structure of the feature of interest but also lead to the generation of erroneous attributes, adversely impacting the confidence of the inferences drawn from the analysis process.

Advancements in technology and programming platforms have opened numerous opportunities for the conception and realization of efficient and effective, completely automated computational solutions for digitization. The performance of such a digitization technique greatly depends on its cohesion with the knowledge bases conceived for it. Techniques like preprocessing (for noise removal), refinements (like erosion, dilation, thinning, resolving m-connectivity, and hole filling), and feature generation (through efficient traversal and need-based interpolation) greatly help in elevating the overall quality of the results, consequently contributing to the confidence of the inferential study.

In addition, automatic digitization techniques may be further advanced to handle omissions, generate and incorporate features in situations of deficiency, and produce quantifiable attributes for elevating the quality and representation of the digitized features. Automatic digitization, if implemented with the desired precision and adequate knowledge, would help to overcome the inherent lags of manual and semi-automatic approaches with reduced effort, time, and cost requirements.

In pursuit of realizing knowledge-enabled automatic digitization, refinement, and visualization processes for morphological features, this research initiative attempts to:

- Automatically extract river patterns and generate attributes based on preconceived hydrological characterizations. With due regard to the above, this section of the research initiative proposes an effective and efficient generic knowledge-based automated computational program equipped with a proficient spiral traversal technique capable of accurately digitizing river networks of different types with advanced abilities for generating various stream attributes with the desired level of confidence.

- Automatically extract contour lines, their need-based refinements, and the generation of associated attributes for facilitating reproduction and representation. With due regard to the above, this section of the research initiative is motivated towards the conception and implementation of an integrity-preserving reconnection mechanism for reconnecting broken contour lines (originating due to overlapping of morphological features) to ensure continuity, relying on concepts such as the sign of gradient, euclidean distance, and modified Bezier curve drawing technique.

- Automatically localize and recognize embedded text for associating semantics necessary for elevating the understanding of associated features: With due regard to the above, this section of the research initiative relies on two distinct subprocesses dedicated to localization and recognition of annotation. Localization was achieved through the use of morphological operators and a convolutional neural network-based deep architecture. Further, the recognition has been performed with the help of a convolutional recurrent neural network and YOLOv8. Additionally, the volumetric enhancement on the original elevation values dataset was implemented through various data augmentation techniques.

- Need-based orientation of morphological features for effective visualization. With due regard to the above, this section of the research initiative realizes techniques for identifying, studying, and understanding the significance of various possible structural orientations in contours and subsequently applies the acquired knowledge to design a computational model for traversal, interpolation, and the generation of shape-preserving contours in between the existing contours. To strengthen the ability of the proposed technique, an exhaustive unsupervised computational model was built for identifying all possible structural operators considering sizable samples. The structural operators were closely analyzed to assign an appropriate angular direction for traversal based on some feature-specific reference points. Subsequently, the distance values of the directional movements were appropriately portioned to place suitable operators for the generation of interpolated contours. The interpolated contours were then refined to ensure continuity. Eventually, the contours were projected onto the z-plane for effective visualization.