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Creating Gauge Polygons: A Fuzzy Logic Approach

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While rain gauge observations are recognized as a precise measure of precipitation at point locations, extending these measurements to cover a continuous spatial grid has always been a challenge. The naive method, Thiessen polygons, extends gauge observations over a spatially explicit grid simply by, the minimum distance to the gauge. Recent work by Cho et.al. 2017 and Zhang et.al. 2017 improved on that approach in introducing the concept of gauge polygons. They define the area encompassing a rain gauge such that the gauge observation best represents precipitation throughout the polygon. However, in those research papers a single factor was chosen to determine the gauge polygon extent: weather radar.

Many efforts have focused on merging gauge observations with other spatially distributed data such as weather radar, through quantitative precipitation estimation (QPE) using various geostatistical interpolation methods. These methods are employed in operational weather forecasting, however, due to the complexities of mixing various data sources, and computation time, results from QPE systems are not immediate. This current work addresses both the time lag and single factor issues in the existing methods of extending point observations. We cast gauge observations to the surrounding areas by considering additional factors. Using a fuzzy logic model, gauge polygons are delineated from a combination of topographic and climatic factors: weather radar precipitation, elevation, aspect and distance from the sea. Furthermore, once a target region is sectioned into gauge polygons, the spatially explicit precipitation grid can be obtained immediately from gauge observations.

Fuzzy logic probabilities (membership functions) for each factor are chosen and then merged by a joint membership function to define each gauge polygon. Weights for each factor in the joint membership function are determined by applying an optimization procedure. Once the gauge polygons are prepared, validation of the model is performed by joining aggregated rainfall from gauge observations of a different storm event, and comparing the resulting spatial precipitation distribution to accumulated weather radar rainfall for that validation period.

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