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# The Use of Rule-Based Cellular Automata to Track and Forecast the Dispersal of Classical Biocontrol Agents at Scale, with an Application to the Fopius arisanus Fruit Fly Parasitoid

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**Abstract :** Ecosystems are networks of organisms and populations that form a community of various species interacting within their habitats. Such habitats are defined by abiotic and biotic conditions that establish the initial limits to a population's growth, development, and reproduction. The habitat's conditions explain the context in which species interact to access resources such as food, water, space, shelter, and mates, allowing for feeding, dispersal, and reproduction. Dispersal is an essential life-history strategy that affects gene flow, resource competition, population dynamics, and species distributions. Despite the importance of dispersal in population dynamics and survival, understanding the mechanism underpinning the dispersal of organisms remains challenging. For instance, when an organism moves into an ecosystem for survival and resource competition, its progression is highly influenced by extrinsic factors such as its physiological state, climatic variables and ability to evade predation. Therefore, greater spatial detail is necessary to understand organism dispersal dynamics. Understanding organisms dispersal can be addressed using empirical and mechanistic modelling approaches, with the adopted approach depending on the study's purpose Cellular automata (CA) is an example of these approaches that have been successfully used in biological studies to analyze the dispersal of living organisms. Cellular automata can be briefly described as occupied cells by an individual that evolves based on proper decisions based on a set of neighbours' rules. However, in the ambit of modelling individual organisms dispersal at the landscape scale, we lack user friendly tools that do not require expertise in mathematical models and computing ability; such as a visual analytics framework for tracking and forecasting the dispersal behaviour of organisms. The term "visual analytics" (VA) describes a semiautomated approach to electronic data processing that is guided by users who can interact with data via an interface. Essentially, VA converts large amounts of quantitative or qualitative data into graphical formats that can be customized based on the operator's needs. Additionally, this approach can be used to enhance the ability of users from various backgrounds to understand data, communicate results, and disseminate information across a wide range of disciplines. To support effective analysis of the dispersal of organisms at the landscape scale, we therefore designed Pydisp which is a free visual data analytics tool for spatiotemporal dispersal modeling built in Python. Its user interface allows users to perform a quick and interactive spatiotemporal analysis of species dispersal using bioecological and climatic data. Pydisp enables reuse and upgrade through the use of simple principles such as Fuzzy cellular automata algorithms. The potential of dispersal modeling is demonstrated in a case study by predicting the dispersal of Fopius arisanus (Sonan), endoparasitoids to control Bactrocera dorsalis (Hendel) (Diptera: Tephritidae) in Kenya. The results obtained from our example clearly illustrate the parasitoid's dispersal process at the landscape level and confirm that dynamic processes in an agroecosystem are better understood when designed using mechanistic modelling approaches. Furthermore, as demonstrated in the example, the built software is highly effective in portraying the dispersal of organisms despite the unavailability of detailed data on the species dispersal mechanisms.

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