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Synchronizing cellular automata to forecast earthquakes

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We have noted that it is possible to partially synchronize several cellular automata with another one, and use this synchronization to forecast the latter [1]. This can improve attempts at forecasting synthetic earthquakes in cellular automata. Also, it opens the possibility of partially synchronizing cellular automata with real faults, for trying to forecast real earthquakes.

Let us explain how to synchronize two cellular automata that simulate the plane of a seismic fault. Consider two models (identical or similar), running simultaneously and independently. One (the *master*) evolves freely. We shall force the evolution of the other one (the *clone*), so that it will be partially synchronized with the master. In order to achieve this, the following rules will be applied in each time step:

- If the master does not generate an earthquake, force the clone in such a way that it does not generate an earthquake either.

- If the master generates an earthquake, force the clone so that it suffers an earthquake of the same size (that is, with the same rupture area and/or coseismic slip).

This causes the clone to be partially synchronized with the master (even without knowing what is exactly going on in the master). Then, if the clone indicates that a big earthquake is impending, one can turn on an “alarm”, and await the next big one in the master. To calibrate the strategy, several clones can be used, not only one. This is somewhat similar to the ensemble (set of models) used in weather forecasts.

We have explored these ideas with the Minimalist Model [2], a stochastic one-dimensional cellular automaton that sketches an individual fault. In this simple model only the rupture area can be considered. The forecasting strategy based on synchronization renders better results than other, more "classical" ones [3].

Note that the rupture area and coseismic slip distribution of real earthquakes can be measured from seismic data. Then, we might use a real fault as a master for one or several models running in real time:

- If no earthquake is generated by the fault, we could force the model(s) to avoid producing any synthetic earthquake.

- If the fault generates an earthquake, we could force the model(s) to produce an earthquake with the same rupture area and/or coseismic slip.

Then, the model (or ensemble of models) probably will be partially synchronized with the real fault, and might be used to extrapolate what is probably going to happen in the fault (for example whether or not a large earthquake is likely to occur).

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[3] Vázquez-Prada, M.; González, Á.; Gómez, J. B. and Pacheco, A. F. (2003). Forecasting characteristic earthquakes in a minimalist model. *Nonlinear Processes in Geophysics*, 10 (3), 565-571.