Tirailleur

a fire perimeter spread model which allows reverse simulation, or

There and Back Again

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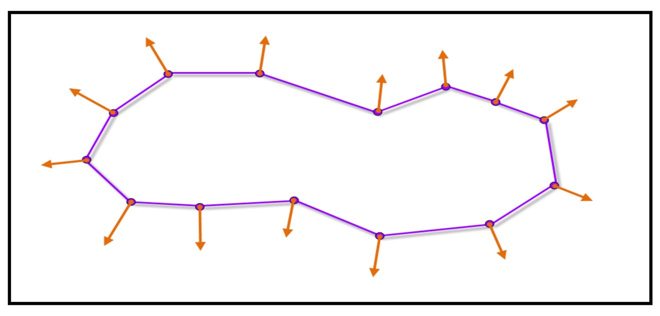
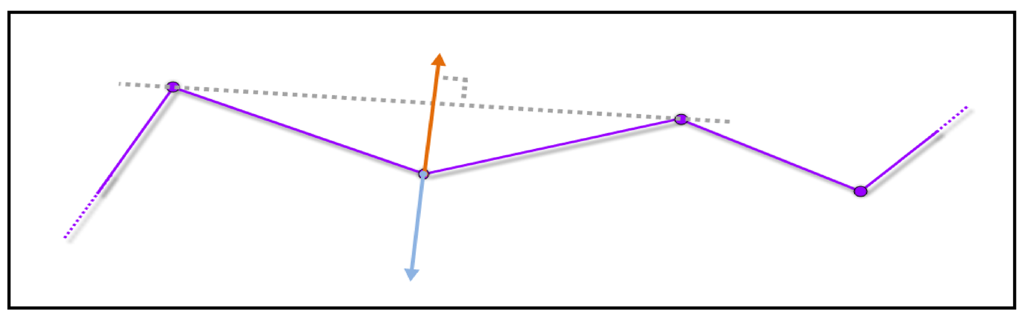
Perimeter evolution

Nodes move outwards, expanding the perimeter as the simulation advances in discrete time steps.



The move direction for each node is determined by considering its two neighbours.



A line is drawn between the nodes on either side of the moving node, and the move direction is perpendicular to that line (see orange arrow).

When contracting, the direction of movement is simply rotated 180 degrees (see blue arrow). This is not an exact reversal: some information is lost so the contraction does not perfectly follow the expansion, especially when the line is very irregular.

In each time step:

- move direction for every node is calculated,
- corresponding rate of spread (ROS) is obtained from the driving model,
- safe time step is dynamically calculated (see below),
- move vectors for all nodes are applied,
- nodes are inserted and removed to maintain line fidelity,
- deep invaginations and line contortions are detected and removed.

The time step must be limited or the nodes may travel too far and skip over significant spatial variations in the ROS. For each time step, the maximum ROS of all the nodes is calculated and used to derive the maximum safe time.

ROS is directional

Perimeter spread algorithms used in models such as FARSITE (Finney, 2004) and Prometheus (Tymstra *et al*, 2009) use the maximum ROS and corresponding direction. This drives the movement of perimeter nodes. In Tirailleur, the direction of spread for each node arises from the perimeter geometry itself, and becomes one of the input arguments for the ROS calculation.

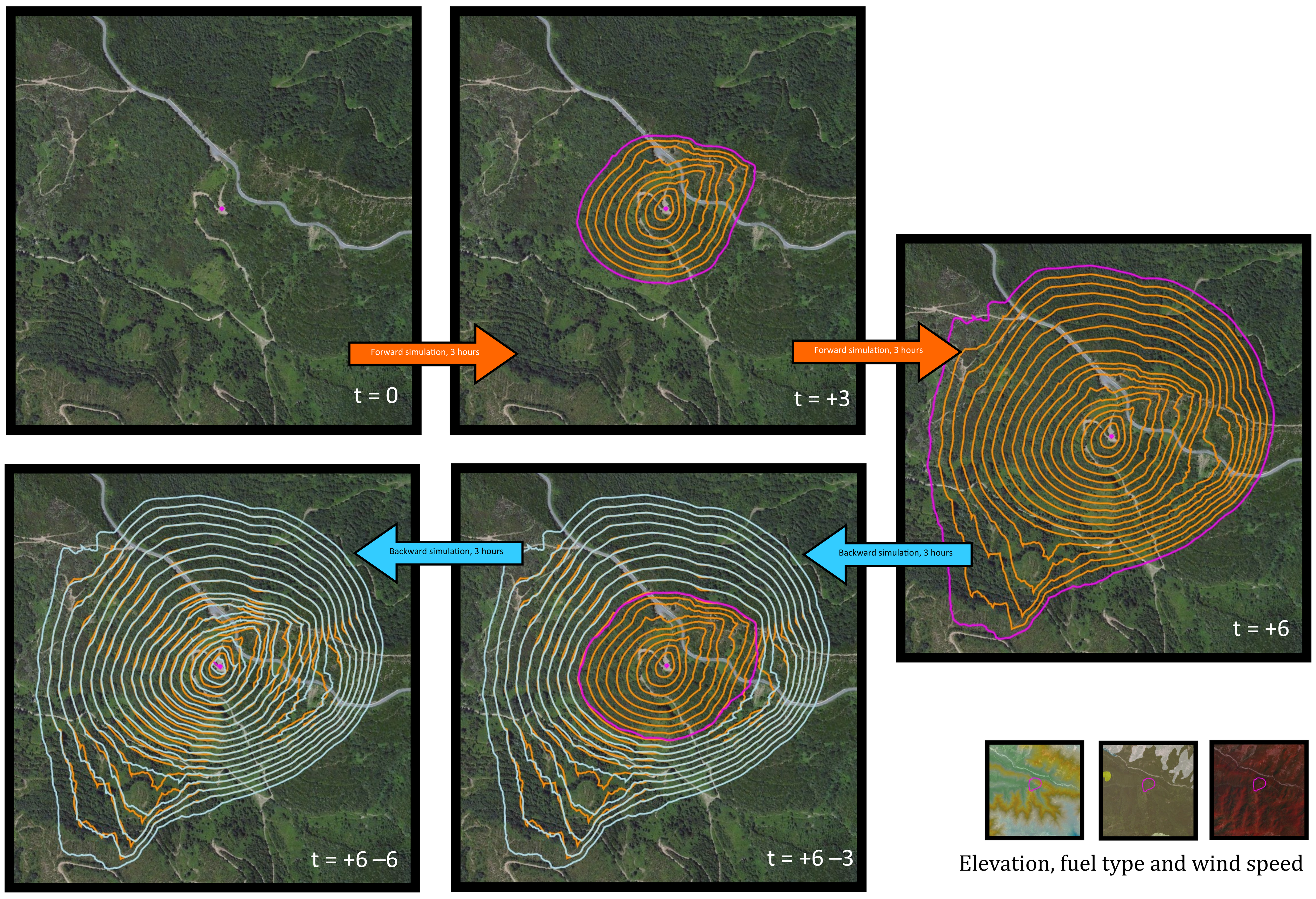
The geometry is more straightforward than the elliptical spread and wavelet approach used in other models, but now the ROS function must return a value for the movement of each node.

Contortion problems

The developing perimeter can become contorted. Loops form by nodes crossing each other's paths. These problems are typical of such models and have been well documented since their inception. (For example, Knight and Coleman, 1993; Bose *et al*, 2009).

Our approach is simple. After each time step, we explore the perimeter to detect contortions. These are clipped out from the line, and the perimeter is reformed.

Expansion and contraction



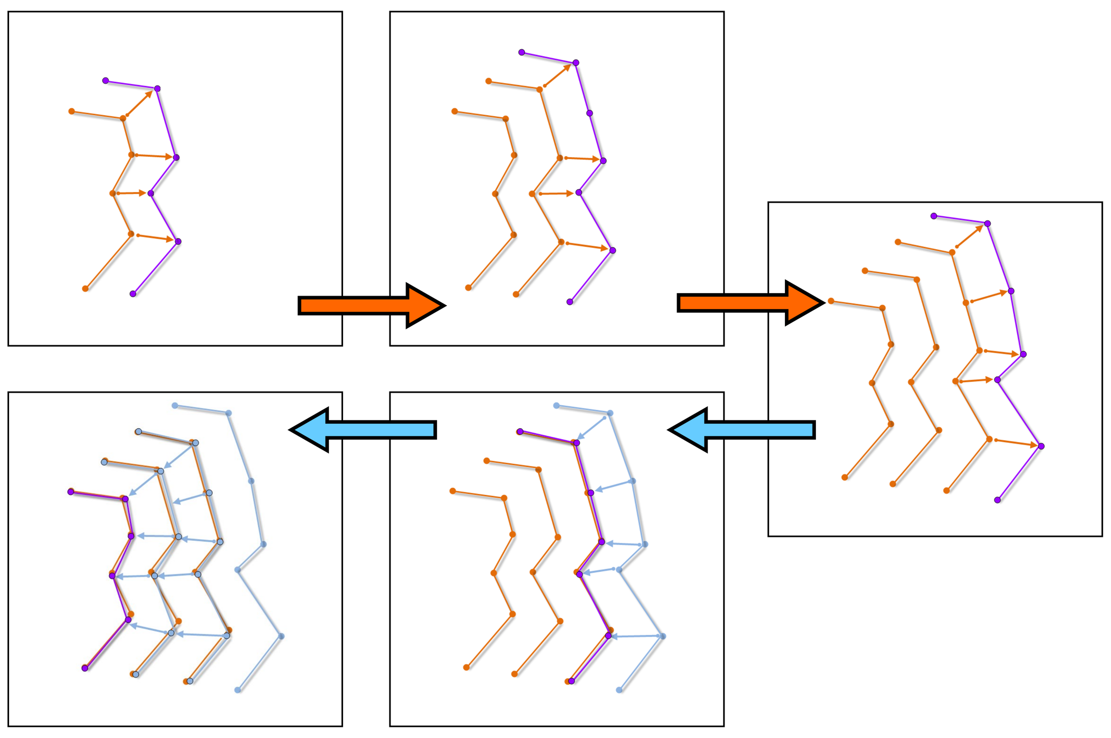
Elevation, fuel type and wind speed

The burning perimeter (purple) spreads from the starting point (small purple square), leaving behind orange time contours.

After several hours of forward simulation, the simulation is manually stopped (the fire does not go out), and is then run in reverse. The active perimeter collapses, leaving light blue time contours.

Eventually, the contracting fire line arrives at or near the initial starting point as the reversed simulation time approaches the start time.

The contracting lines do not precisely match the corresponding expansion contours, especially where the rate of spread is higher, but there is often consistent agreement between the starting expansion location and the terminal collapse location.



Post-fire investigations

The reversibility of the perimeter spread obviously invites us to attempt estimation of an (unknown) fire origin location from a (known) final perimeter.

Tirailleur is used in 'Tiger MEG': an application to support post-fire investigations in Italy. (See oral presentation Tuesday 2015-05-26 17:10, Giannino.)

The perimeter contraction is driven by simple ROS algorithm based on BEHAVE (Andrews, 1986), using standard fuel models. Testing of this application against historical cases is now underway.

Code is available

Open-source example code is available on CodePlex, along with some technical documentation. The code provides a complete implementation of the Tirailleur approach, including our latest attempt at rapid contortion resolution.

Visit tirailleur.codeplex.com or scan the QR code.

For more information, reach us at www.worldinabox.eu

References:

Andrews PL (1986) BEHAVE: fire behavior prediction and fuel modeling system- BURN subsystem, Part 1. USDA Forest Service General Technical Report INT-194.

Bose C; Bryce R; Dueck G (2009) Untangling the Prometheus Nightmare. Proc. 18th IMACS World Congress MODSIM09, Australia.

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Knight I; Coleman J (1993) A fire perimeter expansion algorithm based on Huygens' wavelet propagation. Int. J. Wildland Fire 3(2):73–84.

Tymstra C; Bryce RW; Wotton BM; Armitage, OB (2009) Development and structure of Prometheus: the Canadian wildland fire growth simulation Model. Nat. Resour. Can., Can. For. Serv., North. For. Cent.. Inf. Rep. NOR-X-417.