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Hypothesis assessment with qualitative reasoning : modelling the intermittent Fontestorbes fountain.

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Abstract

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The ecological knowledge about a natural phenomenon can be sparse and the structure of the system hidden and not accessible. In such conditions the system appears more or less like a black box, for which only the inputs and the outputs are known. Most of time several hypothesis can be envisaged to explain the phenomenon, and there is a need to investigate only the ones that are causally sound and that can really explain the observed behaviour.
Conceptual models are commonly used to formalise an hypothesis about a mechanism. They are build prior to experimentations, mathematical models or small-scale models to represent and clarify the idea (Jorgensen and Bendorrichio, 2001). However the soundness of these conceptual models, and then of the hypothesis, can hardly be discussed if the consequences of these representations cannot be simulated and explained.
Qualitative reasoning (Weld and de Kleer, 1990) provides means to capture the conceptual knowledge of experts as qualitative models can in turn be used to run qualitative simulations and provide explanations of the results (Bredeweg and Salles, 2009). Qualitative simulations allow to assess the correctness of a conceptual model from a causal point of view and assess whether the model can exhibit the expected behaviours or not. Therefore qualitative models can support a critical assessment of the hypothesis.

In this work we illustrate the use of qualitative models to test an hypothesis about the functioning of a system. We have developed a qualitative model of the intermittent rate of flow of the Fontestorbes fountain (Ariège, France) using Garp3, a qualitative reasoning modelling environment (Bredeweg et al., 2009). The fountain is a re-emergence that comes out of a mountain. The mechanism behind this surprising phenomenon is hidden, since the inner part of the mountain is not accessible. Besides the regular intermittence of the rate of flow, the fountain has the following characteristics (Mangin, 1969):

1. the draining outflow and the inflow are of the same order of magnitude,
2. the duration of the phases of the cycle are close.

Since the middle of the 19th century scientists have proposed different models to explain the phenomenon. Until the work of Mangin in 1969, the fountain was compared to a siphon, i.e. a reservoir fed continuously by an inflow and drained by a channel with an inversed U shape. Under specific conditions the siphon behaves as a permanent oscillator and the outflow is intermittent.
We have developed a qualitative model of a siphon which exhibits the intermittent behaviour if the conditions are fulfilled. The qualitative model shows that the behaviour of a siphon is controlled by the value of the difference: Inflow-Outflow. In particular, the intermittent behaviour occurs when the inflow is lower than the minimum value of the outflow that can come out when the siphon is full.
Nevertheless the qualitative model provides also a reason to refute the hypothesis of the siphon. With a siphon, the fact that the duration of the two phases of the cycle are close (point 2 cf. above) implies that the value of the draining outflow has to be greater than twice the value of the inflow, which is not consistent with the point 1 (cf. above). Then we envisage the mechanism proposed by Mangin (1969), a more complex mechanism still based on siphons, which is the hypothesis commonly accepted so far.

The qualitative model is used to refute hypothesis only on the basis of facts and conceptual reasoning. We are able to reproduce a substantial part of the reasoning performed by the scientists about the mechanism of the fountain of Fontestorbes using qualitative models and accessible information.
Qualitative reasoning provides means to formally build a conceptual model from an hypothesis and then assess its consistency from the analysis of the simulations. If the qualitative model does not exhibit the expected behaviour then the hypothesis should be rejected. If the general features of the behaviour are simulated but certain conditions are not respected, as it is the case in our example, then the hypothesis can probably be adapted accordingly. The assessment of an hypothesis using a qualitative model leads the modeller to consider different aspects of the phenomenon; this provides a firm ground for the next steps, experimentations or mathematical modelling.

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