PARALLEL AND EVOLUTIONARY APPLICATIONS TO CELLULAR AUTOMATA MODELS FOR MITIGATION OF LAVA FLOW INVASIONS

Abstract. In the lava flow mitigation context, the determination of areas exposed to volcanic risk is crucial for diminishing consequences in terms of human causalities and damages of material properties. In order to mitigate the destructive effects of lava flows along volcanic slopes, the building and positioning of artificial barriers is fundamental for controlling and slowing down the lava flow advance.

In this thesis, a decision support system for defining and optimizing volcanic hazard mitigation interventions is proposed. The Cellular Automata numerical model SCIARA-fv2 for simulating lava flows at Mt Etna (Italy) and Parallel Genetic Algorithms (PGA) for optimizing protective measures construction by morphological evolution have been considered.

In particular, the PGA application regarded the optimization of the position, orientation and extension of earth barriers built to protect Rifugio Sapienza, a touristic facility located near the summit of the volcano.

A preliminary release of the algorithm, called single barrier approach (SBA), was initially considered. Subsequently, a second GA strategy, called Evolutionary Greedy Strategy (EGS), was implemented by introducing multibarrier protection measures in order to improve the efficiency of the final solution. Finally, a Coevolutionary Cooperative Strategy (CCS), has been introduced where all barriers are encoded in the genotype and, because all the constituents parts of the solution interact with the GA environment, a mechanism of cooperation between individuals has been favored. Solutions provided by CCS were extremely efficient and, in particular, the extent of the barriers in terms of volume used to deviate the flow thus avoiding that the lava reaches the inhabited area was less than 72% respect to the EGS and 284% respect to the SBA. It is also worth to note that the best set of interventions provided by CCS was approximately eighteen times more efficient than the one applied to divert the lava flow away from the facilities during the 2001 Mt.Etna eruption.

Due to the highly intensive computational processes involved, General-Purpose Computation with Graphics Processing Units (GPGPU) is applied to accelerate both single and multiple simultaneous running of SCIARA-fv2 model using CUDA (Compute Unified Device Architecture). Using four different GPGPU devices, the study also illustrates several implementation strategies to speedup the overall process and discusses some numerical results obtained. Carried out experiments show that significant performance improvements are achieved with a parallel speedup of 77.

Finally, to support the analysis phase of the results, an OpenGL and Qt extensible system for the interactive visualization of lava flows simulations was also developed. The System showed that it can run the combined rendering and simulations at interactive frame rate.

The study has produced extremely positive results and represents, to our knowledge, the first application of morphological evolution for lava flow mitigation.