Chapter 46
A Swarm Robotics Approach to Decontamination

Daniel S. F. Alves
Instituto de Matemática, UFRJ, Brazil

E. Elael M. Soares
Escola Politécnica, UFRJ, Brazil

Guilherme C. Strachan
Escola Politécnica, UFRJ, Brazil

Guilherme P. S. Carvalho
Escola Politécnica, UFRJ, Brazil

Marco F. S. Xaud
Escola Politécnica, UFRJ, Brazil

Marcos V. B. Couto
Escola Politécnica, UFRJ, Brazil

Rafael M. Mendonça
UERJ, Brazil

Renan S. Freitas
Escola Politécnica, UFRJ, Brazil

Thiago M. Santos
Escola Politécnica, UFRJ, Brazil

Vanessa C. F. Gonçalves
UFRJ, Brazil

Luiza M. Mourelle
UERJ, Brazil

Nadia Nedjah
UERJ, Brazil

Nelson Maculan
UFRJ, Brazil

Priscila M. V. Lima
Instituto de Ciências Exactas, UFRRJ, Brazil

Felipe M. G. França
UFRJ, Brazil

ABSTRACT

Many interesting and difficult practical problems need to be tackled in the areas of firefighting, biological and/or chemical decontamination, tactical and/or rescue searches, and Web spamming, among others. These problems, however, can be mapped onto the graph decontamination problem, also called the graph search problem. Once the target space is mapped onto a graph G(N,E), where N is the set of G nodes and E the set of G edges, one initially considers all nodes in N to be contaminated. When a guard, i.e., a decontaminating agent, is placed in a node i ∈ N, i becomes (clean and) guarded. In case such a guard leaves node i, it can only be guaranteed that i will remain clean if all its neighboring nodes are either clean or clean and guarded. The graph decontamination/search problem consists of determining

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a sequence of guard movements, requiring the minimum number of guards needed for the decontamination of G. This chapter presents a novel swarm robotics approach to firefighting, a conflagration in a hypothetical apartment ground floor. The mechanism has been successfully simulated on the Webots platform, depicting a firefighting swarm of e-puck robots.

INTRODUCTION

Conflagrations are very delicate situations in which one or multiple heat sources cause an uncontrolled fire in a specific area. The spreading fire can seriously threaten human life and natural environments. They can also cause great destruction due to the risk of ignition when the fire is near explosive substances, like those found in chemical plants and hospitals. In spite of possible causes, a conflagration is defined as a contamination-like situation, in which an infected area can quickly infect neighboring areas.

In a burning apartment, it is extremely difficult and dangerous for the residents to try to extinguish the fire, especially if the area is already almost fully burning. A minimum number of humans have to be placed in specific rooms to use the decontamination agent, e.g., a water jet, and to guarantee that heated spots do not turn into fires again. The risk of this task is high for firefighters because of the unpredictability of the situation: the structure may fall apart, flammable products can cause a fatal explosion, and the smoke can disorientate and asphyxiate people. Therefore, it would be very appealing to have this phase of firefighting performed by non-living agents, such as robots.

Although the case study approached here deals with a small-scale problem, it is the possibility of a large-scale conflagration that motivates the conception of a distributed mechanism able to overcome the inability of tackling such situations with centralized strategies. This work presents a novel and distributed way of performing swarm robotics over problems that can be mapped into a graph decontamination or search problem. The *Scheduling by Edge Reversal* (SER) graph dynamics has been applied to many different resource-sharing problems and the graph decontamination has also been recently identified as such.

A pre-established number of robots will enter a hypothetical apartment and perform a cooperative task. They must extinguish the fire of the entire area, room by room. Each robot behaves like a cleaning agent. So, the presence of one of them in a room is assumed to be sufficient for its decontamination, as long as this agent does not leave the area. The act of cleaning is understood as the robot's ability to throw a water jet around the room and its readiness to extinguish any possible fire source that arises. The robot *has to* stay in the room to be decontaminated at least until all neighboring rooms are also *clean*. If this is not done, the cleaned area can be *infected*, i.e., catch fire, again.

DEFINITIONS

In order to present the problem and its respective solution in a coherent fashion, some concepts that will be use used in this chapter need to be presented. Given a connected graph G and two nodes v and u, which belong to G, if an edge e connects v and u, then v and u are *neighbors*. This implies that they have a relation of adjacency. If two nodes are *neighbors* in G and D results from an orientation of G, then those two nodes are also *neighbors* in D, regardless of the orientation of the edges. The reverse of an orientated edge e from v to u is an orientated edge f from u to v.

For the graph contamination problem, nodes of a graph C are in one of three states: contaminated, clean, and guarded or clean. Contaminated is the initial state of all nodes. A (clean and) guarded

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