Chapter XXIII

A Formal Petri Net Based Model for Team Monitoring

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ABSTRACT

This chapter focuses on a Petri Net-based model for team organization and monitoring. The applications considered are missions performed by several robots that cooperate in different ways according to the goals to be achieved. Formal operations on the Petri Net representing the mission plan allow the dynamic hierarchy of subteams to be revealed and the agents’ individual plans – including the relevant cooperation context – to be calculated. The model also allows several failure propagation ways within the team to be highlighted and local plan repair to be considered. Moreover Petri Nets allow direct implementation, and monitoring and control of the plan at each level of the organization: team, subteams, and individual robots.

INTRODUCTION

Teams of physical agents (robots, UAVs, embedded systems) are more and more considered for missions in dangerous, remote or heterogeneous environments (e.g. search and rescue operations in urban environments). Such teams are usually composed of two to about fifteen robots and may be organized as subteams (e.g. ground and air robots working in pairs) possibly merging or splitting according to the tasks to achieve (e.g. a rendez-vous of two pairs of robots for a four-robot task). A team has to be equipped with methods to reorganize subteams so as to adapt to changes within the team (e.g. robot
failure) or within the environment, to new mission goals... Therefore the architecture for controlling such a team must satisfy the following requirements:

• it must be suited to heterogeneous agents;
• it must support the organization of the team as explicit dynamic subteams;
• it must allow the physical agents to operate in real-time;
• it must allow human operators to supervise the mission at any level: team level, subteam level, physical agent level;
• it must deal with disruptive events and implement a replanning function.

Each agent is equipped with sensors – in order to collect information as well as to detect events – and actuators – in order to perform actions. Events may be categorized as regular events, e.g. start and stop signals of activities and messages, known disruptive events, i.e. events that are likely to happen but whose occurrence time is unknown, and unexpected events. The problem addressed in this chapter is that of offering a complete, integrated framework for multi-robot missions. Such a framework should address mission preparation as well as execution monitoring and error recovery. Therefore the core issues we are dealing with are the following:

• monitor the teamplan and events at any level within the team: team level, subteam level, physical agent level;
• handle disruptions at the most local level possible within the team in order to avoid their spreading over the whole team or avoid unnecessary replanning;
• limit consequences of unknown events to a local level.

Please see Chapter VI “A Formal Framework for Organization Modeling and Analysis” by Popova and Sharpanskykh for more discussion on a formal framework for modeling and analyzing organizations with constraints.

The chapter will focus on a formal Petri net based model that deals with these issues within an integrated framework. The concepts and mechanisms for representing the dynamics of the team organization will be presented. Then failure handling and local repair will be dealt with.

MULTI-AGENT TEAMS AND PETRI NETS

We will consider that:

• some agents are coordinated if these agents interact and at least a part of the interaction is based on information passing;
• some agents collaborate if they are coordinated and if they have common goals;
• a team is a set of agents that are put together as a necessary structure to pool skills and resources in order to satisfy the goals of a mission through collaboration.