

Social cognition, artefacts, and stigmergy revisited: Concepts of coordination

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Abstract

A number of different coordination concepts have been developed to explain how individual activities are coordinated on a social level, and the variety of concepts shows there is an interest in many domains to find such explanations. Stigmergy being one of them, has come to be increasingly applied on various kinds of human activities. In other domains we find other concepts for explaining how environmental resources contribute to work activities or how people use them to structure their work. This paper discusses different coordination concepts, including *stigmergy*, *articulation work*, *coordination mechanisms*, *triggers*, *placeholders*, and *entry points*. The first three concepts are explicitly concerned with coordination among several agents, while the last three instead concern individual activities, but arguably they can be extended to the social level. They also bring an explicitly cognitive dimension to coordination, which is not as salient in the former concepts. The concepts discussed here do have some similarities, but also important differences. They may not be interchangeable, but they could complement each other, or contribute to further elaboration of existing concepts. The stigmergic sign, e.g., could usefully be developed to recognise qualitative differences in its role as a coordination mechanism.

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1. Introduction

Some years ago [Susi and Ziemke \(2001\)](#) made a comparative analysis of social/situated theories of cognition (activity theory, situated action, and distributed cognition) and stigmergy, discussing the coordination paradox, visible in both social insects and human activities. The key elements compared were agents, environment, and artefacts, and the collaborative activity emerging from their interaction. The conclusion made back then was that the considered theories and stigmergy do have some similarities, and that stigmergy could be a common denominator. However, while stigmergy, as a general principle, provides a valuable explanation to the coordination paradox ([Theraulaz &](#)

[Bonabeau, 1999](#)), it may be limited in providing rich descriptions of how seemingly individual activities sum up to coordinated human activity. Hence, the aim of this paper is to discuss some concepts of coordination originating from different areas, and to relate them to stigmergy, which are discussed in the context of a case study at a workplace where most tasks are distributed and individually performed, but result in well organised and coordinated activities at the collective level.

Regarding the issue of defining stigmergy, many definitions are considered vague and too general and many papers on stigmergy are criticised for leading their readers to “believe that it is a simple phenomenon that can be easily dismissed as an environment mediated, and indirect communication mechanism” ([Dipple, Raymond, & Docherty, 2014](#), p. 90; see also, e.g., [Heylighen, 2011–12](#);

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Huang, Ren, & Jin, 2008). However, considering, e.g., Dipple et al.'s (2014) *general theory of stigmergy*, the concept of stigmergy is anything but simple; based on a thorough review of previous research, and by addressing the “what, how, why, where and when” of stigmergy, they constructed a holistic, macro-level general model thereof. Another example is Huang et al. (2008) who constructed a *sign-based model of stigmergy* (SBMS), a unified model that places “sign” at its core. The view on stigmergy adopted here is based on these two theories. Dipple et al. (2014) consider different concepts of stigmergy, which includes *mechanisms* (qualitative/quantitative) *distinctions* (marker-based/sematectonic), and *varieties* (four possible combinations of qualitative/quantitative and marker-based/sematectonic). The variety considered here is qualitative marker-based, according to which “the intentional marker is a sign left as a signal that means something to others in its single form [...] that facilitates coordination” (Dipple et al., 2014, p. 13). Huang et al. (2008) provide an elaborated description of sign, which is considered to have a content that is an agent's behaviour or the product of an agent's activities, is carried by the environment, and can be sensed or observed, and interpreted by other agents. Importantly, these theories consider stigmergy in human activities, which allows us to include a cognitive perspective on agents.

In Susi and Ziemke (2001) it was argued that despite the difference in complexity between social insects and humans, the principles of coordination by use of artefacts can be applied to human activity in order to explain and understand the coordination paradox. Whether stigmergy in fact is applicable on human activity or not, has already been discussed in many papers (e.g., Christensen, 2013; Dipple et al., 2014; Parunak, 2006) and the issue will not be reiterated here. Instead it is assumed that a lot of human activities are stigmergic. After all, as Parunak (2006) states, stigmergy is ubiquitous in human interactions and it “would be more difficult to show a functioning human institution that is not stigmergic, than it is to find examples of human stigmergy” (ibid.). While stigmergy previously has attracted perhaps most interest in areas like Artificial Life (Bonabeau, 1999) and Multi-Agent Systems (Omicini, Ricci, & Viroli, 2008), it has also been applied on animals with known cognitive capacities and it is argued to provide a powerful metaphor for human interactions (Marsh & Onof, 2008; Parunak, 2006). Furthermore, to overcome the limitation of ant-like stigmergy, and to include cognizant agents, the concept of stigmergy has also been expanded to explicitly encompass a cognitively oriented perspective, as seen, e.g., in frameworks on stigmergic cognition (Marsh & Onof, 2008) and cognitive stigmergy (Lewis, 2013; Ricci, Omicini, Viroli, Gardelli, & Oliva, 2007).

Cognitive stigmergy is said to preserve the benefits of “ant-biased” stigmergy of the multi-agent systems field, but also to “promote the full exploitation of the cognitive abilities of agents and of the environment articulation in

artifacts in the stigmergic process” (Ricci et al., 2007, p. 138). Another example is Parunak's (2006) schema for analysis of human–human stigmergy, which includes four varieties of stigmergy based on a binary distinction between marker-based/sematectonic stigmergy, and qualitative/quantitative stigmergy. The schema is then applied to a number of common human activities which demonstrates their stigmergic nature. Stigmergy is also being increasingly applied in various domains concerned with human activities. Some examples are team cognition (Espinosa, Lerch, & Kraut, 2002), team work practices (Christensen, 2013), embodied cognition (Dawson, 2014), information systems and open source software development (Bolici, Howison, & Crowston, 2009; Howison, Østerlund, Crowston, & Bolici, 2012; Marsden, 2013), online creative communities (Secretan, 2013), and systems security (Lugosky & Dove, 2011).

There is vast number of studies on collaboration, cooperation, and coordination of human activities, but few of them have embraced stigmergy as an explanatory concept. Besides stigmergy there are also other concepts and mechanisms for explaining coordination of human activities, but comparisons are scarce. An exception is Christensen (2013) who compared stigmergy, articulation work, awareness, and feedthrough. In his conclusion none of the mentioned concepts are interchangeable with stigmergy, but that they complement each other. Another analysis was made by Bolici et al. (2009), who compared stigmergy, boundary objects, field of work, trading zones, and community of practice. Some of the concepts are similar or clearly related to each other, but as noted by Howison et al. (2012), “they don't take each other's contribution into account” (referring to implicit coordination and stigmergy). The focus of this paper is stigmergy and a few concepts that are, or can be, related to coordination in human activities, used foremost in cognitive science, human–computer interaction, and computer-supported cooperative work. The concepts discussed here are *articulation work* and *coordination mechanisms* (Schmidt & Simone, 1996), *triggers* and *placeholders* (Dix, Ramduny-Ellis, & Wilkinson, 2004, and *entry points* (Kirsh, 2001) (concepts like boundary objects and trading zones, which were compared by Bolici et al., 2009, are not included since they concern structures for coordination between different communities, while the discussion here considers coordination within a community). These concepts do not seem to have been previously compared and related to stigmergy, although three of the concepts (triggers, placeholders, entry points) have been combined as a means for understanding the role of artefacts in social interactions (Susi, 2005). Some of the concepts were originally formulated with regard to individual activities, but the discussion will consider their possible role in coordinating activities on a collective level. For the sake of clarity, the term coordination mechanism, as used in the field of computer-supported cooperative work, will be denoted “coordination mechanisms (CMs)” to distinguish it from stigmergic coordination mechanisms.

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