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A team-based holonic approach to robotic assembly cell control

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Abstract

Holonic systems are systems that are modelled in terms of components (holons) that have their own unique identity but are part of a larger whole. This larger whole is known as a holarchy. The manufacturing community has recognised the potential benefits of the holonic approach and it has attracted much interest over the past decade. This paper describes elements of a reference model for holonic manufacturing systems in which holons are characterised by the services that they provide and the services that they require other holons to perform on their behalf. In addition, individual holon behaviours are specified in terms of services, providing the ability for behaviours to be specified in a resource independent manner. We expect that this will result in the construction of systems that are easier to understand, extend and modify. An implementation of the model for the control of an industrial strength manufacturing system is described. An interesting feature of the manufacturing system is that the existing controllers are retained, thus demonstrating that holonic control can be implemented using conventional control hardware.

1. Introduction

The modern manufacturing environment is characterised by small batch sizes, large product variety and short lead times. The centralised approaches of the past have often

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proved inadequate in these highly reactive environments and alternative approaches are required. Agent-based approaches have attracted much interest but have had limited uptake by industry due to a lack of implemented systems. A contributing factor towards this is that existing approaches are usually heterarchical—there is no imposed hierarchy and agents interact as peers in performing tasks. This makes optimisation difficult and does not admit that manufacturing enterprises do have structure—for example, enterprises consist of factories, factories consist of manufacturing cells, and manufacturing cells consist of machines. While this structure exists, it does not constrain behaviour within the enterprise to be hierarchical. Autonomy is still possible at the different levels, but when appropriate, a higher level may coordinate the behaviour of lower levels, for example to optimise throughput. This distinction between structure and behaviour is at the heart of the holonic approach, in which systems are modelled in terms of components (holons) that have their own unique identity but are part of a larger whole. This larger whole is known as a holarchy. The manufacturing community has recognised the potential benefits of this approach, and it has attracted much interest over the past decade. However, the focus of that work has been on holons operating within a heterarchy, not a holarchy.

In 1967, the Hungarian author and philosopher Arthur Koestler proposed the word ‘holon’ to describe a basic unit of organisation in biological and social systems (Koestler, 1967). ‘Holon’ is a combination of the Greek word *holos*, meaning whole, and the suffix *on*, meaning particle or part. Koestler observed that in living organisms and in social organisations, entirely self-supporting non-interacting entities did not exist. Every identifiable unit of organisation, such as a single cell in an animal or a family unit in a society, consists of more basic units (plasma and nucleus, parents and siblings) while at the same time forming a part of a larger unit of organisation (a muscle tissue or community). A holon, as Koestler devised the term, is an identifiable part of a system that has a unique identity yet is made up of subordinate parts and in turn is part of a larger whole. The strength of holonic organisation, or holarchy, is that it enables the construction of very complex systems that are nonetheless efficient in the use of resources, highly resilient to disturbances (both internal and external) and adaptable to changes in the environment in which they exist. All these characteristics can be observed in biological and social systems.

The applicability of Koestler’s concept to manufacturing was first noted by Suda (Suda, 1990). These observations led to the formation of the HMS (Holonic Manufacturing Systems) project in 1993 with a feasibility study prior to the commencement of Phase 1 of the project. The HMS project (http://hms.ifw.uni-hannover.de) was conducted under the auspices of the IMS (Intelligent Manufacturing Systems) program (http://www.ims.org). The concept of the IMS program was formulated in Japan in 1988 on the premise that international cooperation was required to significantly advance research and development in manufacturing technology (Yoshikawa, 1993). The HMS project was one of the first IMS projects and remains one of the largest undertaken. The project spanned 11 years (1993–2004) and three distinct phases. Over 50 organisations from Canada, USA, Europe, Japan and Australia were involved. While the size of the HMS project was impressive, it should be noted that research into holonic manufacturing systems was not restricted to the HMS project and much research (including the work described here) was conducted outside of the HMS consortium.