Chapter 3
Relationships to Other Concepts

Kyrre Glette, Peter R. Lewis, and Arjun Chandra

Abstract This chapter will relate our concepts of computational self-awareness and self-expression to other efforts in computer science and engineering under the self-awareness label. Depending on the fields, the term self-awareness may have different meanings and may be more or less defined. Considering mainly disciplines which explicitly cover self-awareness, we present a selection of clusters of research, and their interpretation of the term. The examples range from basic, but efficient, electronic communication systems, through self-awareness in robotics and large IT systems, to more abstract and formal concepts of self-awareness emerging collectively through interaction of simple nodes. While there are many examples of work addressing self-awareness at different levels, there still seems to be a lack of general definitions and frameworks for working with self-awareness and self-expression in a computing context.

3.1 Introduction

Various research initiatives have used the term *self-awareness* explicitly to describe a property of their computing machinery within computer science and engineering. In some cases, the literature goes further and attempts to define what self-awareness might mean in the context of that research. From these initiatives, a number of clusters stand out as significant efforts to incorporate self-awareness into computing systems. However, in our view, there is a lack of a shared understanding of self-awareness concepts between these clusters. Additionally, these existing efforts have

Kyrre Glette
University of Oslo, Norway, e-mail: kyrrehg@ifi.uio.no

Peter R. Lewis
Aston University, UK, e-mail: p.lewis@aston.ac.uk

Arjun Chandra
Studix, Oslo, Norway, e-mail: arjun@studix.com

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not in our view been sufficiently based on real concepts of self-awareness from psychology; rather the term self-awareness has been used as an informal description for desirable properties which might appear to fit it. In other cases, self-awareness has been identified in the literature as a likely beneficial property for computing systems to possess, though this has been elaborated on little and the term is left largely undefined. One of the potential causes for this lack of a systematic treatment of the term is likely the apparent disagreement on a universal definition for it within neuroscience and psychology literature. Computer science and engineering, where researchers tend to have a more practical approach to specifying concepts, have therefore banked on intuition for a definition, driven more by the solutions to the immediate computational problems of interest than by philosophical considerations.

Even though there is little agreement on the definition of the term both in psychology and computer science, there is a general agreement that self-awareness in computing systems, howsoever intuitively defined, can be beneficial. Some of these benefits have been summarised by Schaumeier et al. [351]. In general, the problem that self-awareness tends to address in a major portion of computing literature can primarily be characterised as the increasing difficulty we face in managing systems with physically or logically distributed autonomous components. Crucially, it is commonly believed that there is a limit to which any component may be able to dictate the behaviour of another. Decision making towards optimising system-level goals in such decentralised systems is therefore distributed across the components, each having access to partial information, which may further be unreliable in terms of the extent to which it is causally relevant to globally optimal decision making. It has been argued that components that possess self-awareness as some form of introspection capabilities [351] may aid the system towards globally efficient decisions. Intuition suggests that introspection may allow components to get fairer deals (e.g., fair allocation of tasks) for themselves out of interactions with their non-dictating and potentially unreliable neighbourhoods. Thus, if all components were to benefit from such interactions, it is likely for the system to benefit as a whole. Self-organisation of this kind may further involve components ascertaining and interacting towards preventing malicious behaviour, whilst managing their own degree of participation and role in the interactions. Additionally, systems which have to deal with humans, e.g., robotic assistants, intelligent tutors and music recommendation systems, also have to manage the degree of interaction necessary over time, so as to do "just enough" for users, thereby preventing disengagement resulting from too much or too little interaction. Such systems can benefit from having a computational notion of how they influence user behaviour.

We now introduce and discuss various clusters of research, each containing a large body of work using some notion of self-awareness. Early work surveying these efforts has been carried out by Lewis et al. [237].

3.2 Self-awareness in Artificial Intelligence

The higher levels of self-awareness, such as the meta-self-awareness introduced in Chapter 2, have been of particular interest in the artificial intelligence community. These concepts overlap significantly with meta-cognition, defined by Metcalfe and Shimamura [264] as *knowing about knowing*. Integration of AI technologies into systems that, as a result of the integration, exhibit self-awareness of this meta-cognitive form has been on DARPA's research agenda for some time [313]. Indeed, architectural issues in building such integrated systems which then exhibit self-awareness were the subject of a DARPA workshop in 2004 [12].

Cox argues that being aware of oneself is not merely about possessing information, but being able to use that information in order to generate goals, which may in turn lead to the information being modified [84]. Importantly, Cox also suggests that meta-cognition is similar to the algorithm selection problem, wherein the task is to choose the most efficient algorithm from a set of possibilities. This notion of an ability to select one's own method of collection and processing of information, according to goals which may themselves be modified by the individual, has much in common with the conceptual self discussed in Chapter 2. Cox further considers the differences between cognition and meta-cognition and argues that a meta-cognitive system is one whose domain is itself, such that it can reason about its knowledge, beliefs and reasoning process, as opposed to merely using knowledge about itself. This indeed is a capability of the conceptual self, and our corresponding notion of meta-self-awareness, discussed in Chapter 2.

3.3 Self-awareness in Collective Systems

A key concept inspiring our definition of computational self-awareness, as discussed in Chapter 2, and also our reference architecture, discussed in Chapter 4, is the notion that self-awareness can be an emergent phenomenon, arising from interactions within a collective system. Moreover, a self-aware system under consideration may be composed of a set of heterogeneous nodes which individually possess various levels of self-awareness, and it is also possible to consider self-awareness at several hierarchical levels. The notions of span and scope of self-awareness, as well as hierarchical considerations, will be elaborated on in Chapter 4.

Several directions of self-aware computing systems research consider systems with nodes at various levels of self-awareness, as well as emergent self-awareness. Examples of these are the autonomic and organic computing paradigms, and the formal modelling undertaken in the ASCENS project, which will all be covered in the following sections. One recent example of a hierarchically and collectively self-aware system is the heterogeneous swarm of autonomous underwater vehicles targeted in the CoCoRo project [354]. Here, self-awareness is considered at three hierarchical levels: the individual level, the group level, and the swarm level. At the individual level, the underwater robot needs to determine its own capacity to achieve objectives, and adapt accordingly, while at the group level awareness is present in a mechanism for locating toxic sources. Finally, at the swarm level, self-awareness allows the swarm to monitor global state information and activity, which can lead to adaptation of the swarm behaviour, or sensing when the swarm has completed a task.

3.4 Formal Models for Self-awareness

With a particular focus on distributed or collective self-awareness, recent research has also been conducted on the question of how to formally specify both knowledge and behaviour of self-aware collectives. For example, in the ASCENS[1] project, formal methods are applied to *ensembles* of components (such as robots or cloud computing services). In this project, a symbolic mathematical model for normatively describing a system of interacting components, which is referred to as the *general ensemble model (GEM)*, is proposed [177]. GEM purports to be a common integrated system model for describing components, each normally described using disparate mathematical techniques, and their interactions. In order to construct a mathematical model that can encapsulate such descriptive differences amongst components, the GEM specification works at a higher level of abstraction, namely, set theory and order theory. One then has to only consider describing an adaptive system as relations between inputs and outputs. Multiple adaptive systems can be combined using a combination operator, allowing a collective to be described as an adaptive system of adaptive subsystems. Importantly, using this combination operator, GEM is able to characterise the combination of the *environment*, the *connections* between the collective and the environment, and the *collective* itself as a system in its own right.

GEM further defines *adaptation domains*, each of which is composed of a range of environments that a collective has to be able to face, the connections between the collective and such environments, and the goals that the collective has to achieve or satisfy. Using order theory, a *preorder of adaptivity* for systems is then possible to specify. With such a formulation of systems, their adaptivity to various environments and against other systems, formal assessment of the adaptive capabilities of a system becomes possible. Indeed, a system that possesses or obtains knowledge of itself and its environment influences its own adaptivity. GEM goes on to further define the notion of *knowledge*. Knowledge that is possessed by the system at the component and at the collective level is modelled as ontologies. A meaningful data structure offers opportunities for inference, e.g., compensating for uncertainty of observations. Moreover, an ontological representation of contextual knowledge allows the component/system to identify known and unknown situations, and learn the relationships between its actions, encountered situations, and goals. Learning allows the system or its components to obtain knowledge at the time of operation in

[1] http://ascens-ist.eu/

the form of *patterns*, influencing how they might manage their goals in the future. Such knowledge, when employed by components to recognise changes taking place internally, at the level of the collective, and in the environment, and to learn about new situations upon detecting a change, provides *awareness* to the components. Part of this conceptualisation of awareness is *self-awareness*, which is defined as the employment of knowledge by a component to *recognise* changes taking place internally. When a component is able to recognise changes taking place at the level of the collective, such recognition abilities are termed context-awareness. Any learning which happens upon change detection forms part of the situational awareness of the component.

Vassev and Hinchey [397] discuss in some detail the current state of the art in ontology-based knowledge representation within self-aware collective systems in, and lay out both formal deterministic and probabilistic variants. They argue that this will facilitate better self-awareness through easier analysis of the states and goals of local parts of the system.

3.5 Self-awareness in Engineering

While meta-cognition or meta-self-awareness are concerned with higher reasoning abilities, and are of particular interest in artificial intelligence, efforts exist at a more fundamental level to engineer systems which explicitly consider knowledge about themselves. A case for a paradigm shift in system design practice is put forward by Agarwal and Harrod [3] and elaborated on by Agarwal et al. [4]. The idea here is to move from a procedural design methodology wherein the behaviour of the computing system is pre-programmed or considered beforehand (i.e., at design time), towards a self-aware system where this is not required and the system adapts to its context at run-time. One aim is to avoid or reduce the need to consider the availability of resources and various other constraints beforehand, instead intelligently trading-off available resources for performance at run-time.

Importantly, for a system to be self-aware it is not required that it be highly complex; indeed, the scalability of the concept means that self-awareness has also been considered in much simpler systems. An example of this is the so-called *cognitive radio devices* [133], which monitor and control their own capabilities and also communicate with other radio devices to monitor theirs. This enables them to improve the efficiency of communication by negotiating changes in parameter settings [404]. In this case, it is the system's ability to monitor and reason about its operational capabilities that is used to justify the label self-aware. Specifically, a self-aware radio device

> *"needs to understand what it does and does not know, as well as the limits of its capabilities. This is referred to as self-awareness. For instance, the radio should know its current performance, such as bit error rate (BER), signal-to-interference and noise ratio (SINR), multipath, and others. In a more advanced case, the agent might need to reflect on its previous actions and their results. For instance, for the radio to assess its travel speed a fortnight*

> *ago between locations A and B, it might be able to extract parameters from its log file and do the calculation. For the radio to decide whether it should search for the specific entries in the log and then perform appropriate calculations (or simply guess), it needs to know the effort required to perform such a task and the required accuracy of the estimate to its current task"* [133, p. 405]

Driven by the need for satisfying heterogeneous QoS requirements across future multimedia networks, distributed monitoring and control is increasingly being seen as a viable solution for routing data as well. "Smart" networks, that use an adaptive packet routing protocol called cognitive packet network (CPN) as part of their routing architecture, are reviewed in [347]. CPN enables nodes on the network to monitor and learn at run-time the efficacy with which they can deliver packets that go through them. Node-level monitoring and learning allow the network to continuously adapt the route between a source and a destination, taking into account the potentially changing QoS requirements of nodes falling on the path between these end points. In a manner reminiscent of stigmergy, the successful delivery of a packet carves a route along the network, followed by the nodes along this route receiving feedback pertaining to this success. This feedback is key to run-time learning, enabling packet forwarding decisions to be made at each node. Nodes which are on routes leading to fewer packet losses tend to be preferred for packet forwarding, and exploration of different routes is encouraged through the allowance of a small number of random packet forwarding decisions. A network using CPN as a routing protocol is therefore seen as self-improving, and resilient to changing network conditions. The resilience of networks using CPN to denial of service attacks is shown by Gelenbe and Loukas [144], and self-awareness in the network is attributed to the use of CPN infrastructure with node-level restrictions on bandwidth. Node-level control, enabled by the CPN infrastructure, facilitates nodes' being able to detect and stifle excessive traffic passing through them.

Santambrogio et al. [349] and Hoffman et al. [170] propose the concept of *application heartbeats* as an enabling technology for self-aware computing systems. These heartbeats are intended to establish a standard way of defining application goals and evaluating the performance of a system attempting to achieve those goals. Heuristic and machine learning techniques may then be applied in order to provide adaptation and decision making behaviour. Application heartbeats form part of the SEEC approach [172] to designing self-aware systems.

When engineering a self-aware system, Agarwal argues that five design properties of the system should be considered [4]. Namely, they should be:

- Introspective, i.e., they can observe and optimise their own behaviour,
- Adaptive, i.e., they can adapt to changing needs of applications running on them,
- Self-healing, i.e., they can take corrective action if faults appear whilst monitoring resources,
- Goal-oriented, i.e., they attempt to meet user application goals, and
- Approximate, i.e., they can automatically choose the level of precision needed for a task to be accomplished.

Introspection, the ability to obtain knowledge concerning one's own behaviour, clearly forms part of self-awareness according to the definitions given in Chapter 2. However, subsequent optimisation of the system's behaviour is not directly concerned with the process of obtaining and representing that knowledge. Instead, this optimisation is concerned with the system's subsequent behaviour, thus relating to our concept of self-expression. Goal orientation, for example, requires knowledge of one's own goals, clearly a part of self-awareness. Subsequent behaviour which attempts to meet such goals, however, is not primarily concerned with obtaining or representing the knowledge, and falls under the concept of self-expression.

3.6 Self-awareness in Pervasive Computing

Self-awareness has also been of great interest to the pervasive computing community. Here, research is primarily concerned with systems that are mobile and hence their environment, performance and context changes. As such, these systems need to monitor their own state and their external environment, in order to adapt to changes in a context-specific way. Often monitoring and adaptation are studied in the context of human-computer interaction, since the interest is in how such systems self-adapt in order to be useful to humans in different situations (e.g., "going for a run"). A survey by Ye et al. [419] covers issues and challenges involved in assimilating sensor data from a myriad of sources in order for pervasive computing systems to identify situations which a human user, and hence the system itself, may be in. They show a shift in techniques over time from *logic-based* ones towards those that are *learning-based*, as obtained sensor data has become more complex, erroneous and uncertain, with sensors becoming ever more pervasive. Given currently available model building techniques, the learning of mappings between sensor data and a notion of the situation type poses several challenges. For example, the lack of training data available in rapidly changing contexts in the real world can lead to low performing models. This has been tackled by considering unsupervised learning [156, 46] and web mining [315]. Another line of research within pervasive computing [186] is concerned with constructing simulation models of contexts, in which so-called context-aware applications can learn and be tested.

3.7 Self-awareness in Robotics

One domain where self-awareness would seem an obvious property for success is the field of robotics, and in particular for autonomous and human-like robots. Indeed, architectures for autonomous robots have at least implicitly incorporated several levels of self-awareness and self-expression as defined in Chapter 2 for a long time, such as in *sense-plan-act* and other agent-based architectures [345]. Holland argues [175] that robots could benefit greatly from internal models, and identifies four major areas where such models would be advantageous: when processing novel or incomplete data, for detecting anomalies, for enabling and improving control, and for informing decisions.

Further, Winfield argues [414] that internal models in robots provide a form of self-awareness, and that this property is indeed necessary to achieve safety in unknown or unpredictable environments. By constructing and evaluating internal models of the robot itself and its surroundings, consequences of possible future actions can be evaluated. This kind of self-simulation allows for a possible moderation of the robot controller, such that future unsafe actions are not executed. Interestingly, this also opens up for a form of minimal ethical consideration in robots – robots could be programmed to avoid consequences involving humans being harmed. Another form of self-modelling in robots can be found in the Nico robot [161], where the robot's kinematic model and cameras are calibrated together. This unified approach results in a tightly calibrated self-model with low positional error on the end effector. The same approach was also used for calibrating the use of a tool, by incorporating the tool into the self-model.

Going beyond calibration, a robot building from scratch a self-model of its own morphology is presented in [41]. The model, constructed through exploratory movements, can then be used in the search of an appropriate locomotion pattern. This approach promises resilient robots—if the robot's body is damaged, it can discover this, build a new morphological self-model, and then adjust its locomotion according to the new model. The concepts of self-modelling and self-reflection in robots are further discussed in [40], where self-reflection is stated as an important aspect of self-awareness. An example of such a self-reflective robot is demonstrated in [426], where a robot with two "brains" is constructed—one neural network module monitors the actions of a lower-level neural network module. This is well in line with our concept of meta-self-awareness.

3.8 Self-awareness in Autonomic Systems

One of the key areas of computing research where the term self-awareness litters the literature is autonomic computing. Just over a decade ago, IBM proposed [180] a grand challenge to tackle *"a looming software complexity crisis"* [213]. It was argued that the complexity of computing systems, increasingly composed of distributed, interconnected components would soon be effectively unmanageable by humans, who would be unable to grasp the complexities, dynamics, heterogeneity and uncertainties associated with such systems [371]. Since then, the field of autonomic computing has developed, in an attempt to address this grand challenge. The key idea behind autonomic computing is that such complexity leaves system managers neither able to respond sufficiently quickly and effectively at run-time, nor consider and design for all possible actions of and interactions between components at design-time. Thus, in response, autonomic systems should instead manage themselves at run-time, according to high-level objectives [213].

Indeed, how to achieve effective *self-management* of complex IT systems is the fundamental aim of research in autonomic computing. Here, the concept of self-management is decomposed into four activities: self-configuration, self-optimisation, self-healing and self-protection. Unlike some of the other types of systems described in this chapter (such as meta-cognitive systems and robot swarms), these aims of autonomic systems are geared more towards achieving functional and non-functional goals associated with the management of IT systems, than achieving interesting self-adaptive or self-organising behaviour per se. However, looking deeper, we can see that such behaviours are indeed necessary for systems to self-manage. Indeed, the autonomic computing literature defines [371, 309, 105] four additional properties of autonomic systems, which are required in order to enable the activities above. These are self-awareness, environment-awareness or self-situation, self-monitoring and self-adjustment.

Self-awareness in the autonomic computing literature to date is concerned exclusively with what is described as private self-awareness in the psychological literature, discussed in Chapter 2. Similarly, our notion of public self-awareness can be compared with the notion of situated environment-awareness in autonomic computing, where the environmental knowledge concerned is built up through monitoring and observation, and constructed through modelling and learning at run-time. Finally, self-adjustment, as a form of self-expression, is concerned with behaviour of the autonomic system being based upon such learnt knowledge. Despite the prevalence of the term self-awareness in autonomic computing research, the literature offers little in the way of definition or guidance on conceptually what self-awareness might be in this context.

In order to gain some understanding of the role of self-awareness in autonomic computing, it is helpful to examine how such systems are typically built. Each component in the IT system is managed by a so-called *autonomic manager*, an autonomous agent responsible for monitoring the managed element and its environment, then constructing and executing plans based on an analysis of that information. In addition, a knowledge repository is available to the autonomic manager, containing models of the behaviour and performance of the managed component, which are typically developed and provided by an expert in advance to enable run-time planning. Together, the *monitor-analyse-plan-execute* loop and the knowledge repository are known as the MAPE-K architecture [190], which forms the basis of the design of many autonomic managers. The MAPE-K architecture is depicted in Figure 3.1; as can be seen it has much in common with other general agent architectures, such as those described by [345].

However, a decade since the original autonomic computing concepts were proposed for the management of complex IT systems, autonomic systems research now takes a broader view of applications, architectures and techniques. For example, autonomic systems are commonly now considered to include applications as diverse as pervasive computing [146], communication networks [104] and robotic swarms [427]. Indeed, any networked system which manages itself through autonomous decentralised decision making could be considered autonomic. Appropriately, a generalisation of the original MAPE control loop for autonomic systems, acknowledging

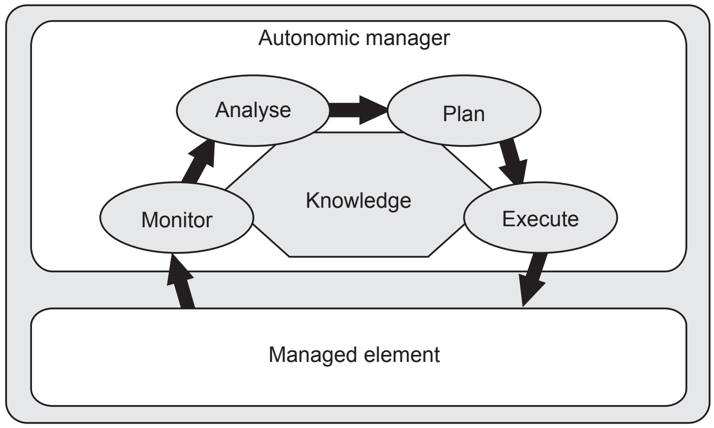

Fig. 3.1 The MAPE-K architecture for autonomic managers (inspired by [190]). The *monitor* and *analyse* components obtain and analyse sensor information. This implements functionality for what are termed self-awareness and environment-awareness in the autonomic computing literature, and can be compared with the concepts of private and public self-awareness introduced in Chapter 2.

that a multitude of techniques could be used to realise each step, is described in [105]. This more generalised autonomic control loop consists of: *collect*, *analyse*, *decide*, *act*. In one example of this generalisation, the analysis and planning steps from MAPE are replaced with a reinforcement learning algorithm [383]. Also in this approach, hybrid knowledge bases, consisting of available domain knowledge and that obtained during run-time, are advocated.

3.9 Self-awareness in Organic Computing

In the absence of system-wide knowledge for decision making and control, the emergence of desirable global behaviour through local interactions is one of the fundamental challenges in complex systems research today. Indeed, desirable emergence is seen as one of the key benefits that autonomous self-aware components could enable in these systems [351]. One research initiative that directly addresses the issue of *desirability* in self-organised, indeed emergent, behaviour of complex systems is organic computing [277]. Desirability is the main research focus here, and, depending on system-level requirements, takes precedence over the degree of autonomy afforded to individual components. According to Schmeck [353], *"it is not a question of whether self-organising systems will arise, but how they will be designed and controlled."*

An organic computing system is said to be strongly self-organised if its components do not rely on any central control for coordination. A weaker form of self-organisation allows for the system boundary to be relaxed by the inclusion of a central *observer* and *controller* within it, thereby making the observation of system-wide objectives carried out by some component, followed by corrective control. Indeed, lowering the degree of autonomy afforded to individual components is therefore the price paid for the achievement of desirable global behaviour. Such concession of autonomy is one major difference between organic and autonomic computing (discussed in Section 3.8), the latter favouring strong self-organisation.

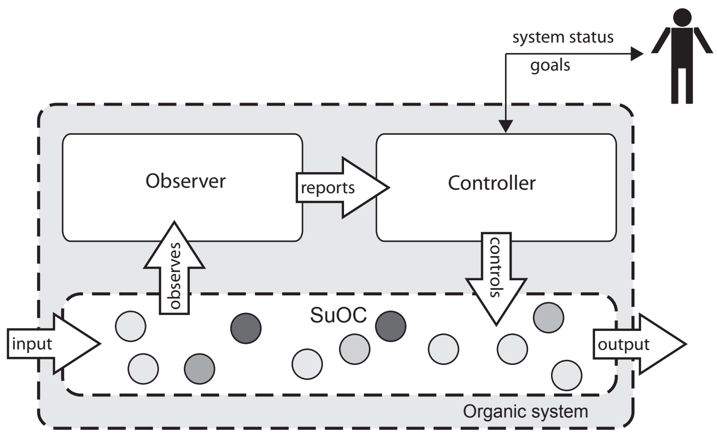

Fig. 3.2 Observer/Controller architecture (inspired by [338]). The organic system under observation and control (SuOC) consists of several self-aware heterogeneous nodes.

The observer and controller approach to governing the emerging global behaviour of a self-organising system is central in organic computing, and a generic Observer/Controller system architecture has been proposed. Here, the decentralised, self-organising system to be governed is called a *system under observation and control* (SuOC), and the observer and controller components are responsible for surveillance and feedback through a control loop [338]. An illustration of this architecture can be seen in Figure 3.2. The observer collects and aggregates behaviour information about the SuOC through sensor information. The resulting system indicators are reported to the controller which can then, based on objective functions, constraints, and overall goals, take actions to influence the SuOC. The architecture has several implementation options: both centralised and decentralised, as well as hierarchical approaches, are possible.

3.10 Self-expression in Computing

Though the notion of self-expression is not common in the approaches to self-awareness in the literature, there is little doubt that the concepts covered by self-expression are implemented and discussed in alternative ways. For example, both the MAPE-K and the Observer/Controller architectures emphasise the distinction between knowledge collection and acting based on this knowledge. Two related, but not similar definitions of self-expression were proposed at the International Conference on Self-Adaptive and Self-Organizing Systems Workshops in 2011, namely the definition of Zambonelli et al. [427] and our own interpretation [237]. Our own interpretation is presented in Chapter 2 of this book; Zambonelli et al., stemming from the autonomic computing community, propose a slightly different approach where

> *"Self-expression mechanisms concern the possibility of radically modifying at run-time the structure of components and ensembles."*

This definition implies a stronger change, and action selection and parameter modification in this context are referred to as self-adaptation. In contrast, our own interpretation of self-expression is wider, encompassing also action selection and parameter modification. Hölzl and Wirsing point out these differences [178], and categorise our definition as *behavioural self-expression* and the definition of Zambonelli et al. as *structural self-expression*. They further build on the definition of behavioural self-expression to also include a *degree* of self-expression, which is based upon how much the given actions work towards the goals of the system.

3.11 Summary

In this chapter we covered several approaches which explicitly use the term self-awareness in computer science and engineering literature, from theoretical levels to hardware implementations.

First, we saw how the artificial intelligence community took particular interest in a higher level of self-awareness—the meta-cognitive approach, similar to our notion of meta-self-awareness. Then, we saw how self-awareness is considered at agent levels, but also how it may appear collectively through interaction of simpler nodes, that is, at higher hierarchical levels in a complex system. The formal modelling approaches of the ASCENS project as well as the organic computing initiative are both explicitly emphasising this kind of collective self-awareness in systems consisting of heterogeneous self-aware nodes. On a more concrete level, the engineering approaches in cognitive radio and cognitive packet networks make use of introspection to monitor their own performance in the network. However not only private self-awareness is displayed, as the nodes also need to assess their performance in relation to the rest of the network, thus introducing public self-awareness as well. In pervasive computing and robotics we saw how self-models of the agent as well as its context were constructed, allowing for sophisticated reasoning and prediction of the outcome of future actions. These models typically comprise almost all levels of computational self-awareness according to our definitions in Chapter 2, i.e., stimulus-awareness, interaction-awareness, time-awareness, as well as goal-awareness, though not necessarily meta-self-awareness. In our final example, the autonomic computing approach tries to tackle the very concrete challenge of managing complex IT systems, through self-management. Autonomic computing distinguishes between self-awareness and situated environment-awareness, corresponding well to our concepts of private and public self-awareness.

It should be noted that there are also several other approaches within engineering and computer science which do not explicitly claim self-awareness, but still operate under similar principles. This becomes true in particular when considering the lower levels of computational self-awareness defined in Chapter 2. Often, the use of self-awareness refers to quite disparate ideas, for example, to highlight quite specific self-monitoring capabilities of a system or to indicate an awareness by the system of the user or context or that a component has a conceptual knowledge of the wider system of which it is part.

Despite the many forms of computational awareness discussed, many approaches, including the big architectural approaches like MAPE-K and Observer/Controller, do agree on the distinction between awareness and action. This key split between functionality responsible for knowledge acquisition and representation and that responsible for knowledge use and behaviour is important, and our concepts of self-awareness and self-expression follow the same line of distinction. However, though implicitly implemented, the concept of self-expression is not widely adopted in a computing context; but it has received increased attention in recent years.

There exist so far few efforts to establish a common framework for describing or benchmarking the self-awareness capabilities of computing systems, or the benefits that increased self-awareness might bring. Still, there seems to be a common understanding that studying self-awareness concepts, and implementing features of self-awareness, is a necessary path to take in order to cope with, and achieve efficiency in, increasingly complex computing systems dealing with dynamic environments. In that endeavour, common notions of what self-awareness and self-expression mean in a computational context would be of utmost importance. Common definitions and frameworks would help us not only to answer questions about the self-awareness properties of a system, such as *what kind of* self-awareness is present, and to *what extent*, but also to reason about the benefits and costs of implementing a certain form of computational self-awareness.

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References

1. Aberdeen, D., Baxter, J.: Emmerald: a fast matrix-matrix multiply using Intel's SSE instructions. Concurrency and Computation: Practice and Experience **13**(2), 103–119 (2001)
2. Abramowitz, M., Stegun, I.: Handbook of Mathematical Functions. Dover Publications (1965)
3. Agarwal, A., Harrod, B.: Organic computing. Tech. Rep. White paper, MIT and DARPA (2006)
4. Agarwal, A., Miller, J., Eastep, J., Wentziaff, D., Kasture, H.: Self-aware computing. Tech. Rep. AFRL-RI-RS-TR-2009-161, MIT (2009)

5. Agne, A., Hangmann, H., Happe, M., Platzner, M., Plessl, C.: Seven recipes for setting your FPGA on fire – a cookbook on heat generators. Microprocessors and Microsystems **38**(8), 911–919 (2014). DOI 10.1016/j.micpro.2013.12.001
6. Agne, A., Happe, M., Keller, A., Lübbers, E., Plattner, B., Platzner, M., Plessl, C.: ReconOS: An Operating System Approach for Reconfigurable Computing. IEEE Micro **34**(1), 60–71 (2014). DOI 10.1109/MM.2013.110
7. Agne, A., Platzner, M., Lübbers, E.: Memory virtualization for multithreaded reconfigurable hardware. In: Proceedings of the International Conference on Field Programmable Logic and Applications (FPL), pp. 185–188. IEEE Computer Society (2011). DOI 10.1109/FPL.2011.42
8. Ahuja, S., Carriero, N., Gelernter, D.: Linda and friends. IEEE Computer **19**(8), 26–34 (1986). DOI 10.1109/MC.1986.1663305
9. Al-Naeem, T., Gorton, I., Babar, M.A., Rabhi, F., Benatallah, B.: A quality-driven systematic approach for architecting distributed software applications. In: Proceedings of the 27th International Conference on Software Engineering, pp. 244–253. ACM (2005). DOI 10.1145/1062455.1062508. URL http://doi.acm.org/10.1145/1062455.1062508
10. Ali, H.A., Desouky, A.I.E., Saleh, A.I.: Studying and Analysis of a Vertical Web Page Classifier Based on Continuous Learning Naive Bayes (CLNB) Algorithm, pp. 210–254. Information Science (2009)
11. Alippi, C., Boracchi, G., Roveri, M.: Just-in-time classifiers for recurrent concepts. IEEE Transactions on Neural Networks and Learning Systems **24**(4), 620–634 (2013)
12. Amir, E., Anderson, M.L., Chaudhri, V.K.: Report on DARPA workshop on self-aware computer systems. Tech. Rep. UIUCDCS-R-2007-2810, UIUC Comp. Sci. (2007)
13. ANA: Autonomic Network Architecture. URL www.ana-project.org. (accessed March 8, 2016)
14. Angelov, P.: Nature-inspired methods for knowledge generation from data in real-time (2006). URL http://www.nisis.risk-technologies.com/popup/Mallorca2006_Papers/A333_13774_Nature-inspiredmethodsforKnowledgeGeneration_Angelov.pdf
15. Apache: Hadoop. http://hadoop.apache.org/docs/r1.2.1/mapred_tutorial.html. (Accessed March 8, 2016)
16. Araya-Polo, M., Cabezas, J., Hanzich, M., Pericàs, M., Rubio, F., Gelado, I., Shafiq, M., Morancho, E., Navarro, N., Ayguadé, E., Cela, J.M., Valero, M.: Assessing accelerator-based HPC reverse time migration. IEEE Transactions on Parallel and Distributed Systems **22**(1), 147–162 (2011)
17. Asanovic, K., Bodik, R., Catanzaro, B.C., Gebis, J.J., Husbands, P., Keutzer, K., Patterson, D.A., Plishker, W.L., Shalf, J., Williams, S.W., Yelick, K.A.: The landscape of parallel computing research: A view from Berkeley. Tech. Rep. UCB/EECS-2006-183, EECS Department, University of California, Berkeley (2006)
18. Asendorpf, J.B., Warkentin, V., Baudonnière, P.M.: Self-awareness and other-awareness. II: Mirror self-recognition, social contingency awareness, and synchronic imitation. Developmental Psychology **32**(2), 313 (1996)
19. Athan, T.W., Papalambros, P.Y.: A note on weighted criteria methods for compromise solutions in multi-objective optimization. Engineering Optimization **27**(2), 155–176 (1996)
20. Auer, P., Cesa-Bianchi, N., Fischer, P.: Finite-time analysis of the multiarmed bandit problem. Machine Learning **47**(2–3), 235–256 (2002)
21. Babaoglu, O., Binci, T., Jelasity, M., Montresor, A.: Firefly-inspired heartbeat synchronization in overlay networks. In: First International Conference on Self-Adaptive and Self-Organizing Systems (SASO), pp. 77–86 (2007)
22. Babenko, B., Yang, M.H., Belongie, S.: Robust object tracking with online multiple instance learning. IEEE Transactions on Pattern Analysis and Machine Intelligence **33**(8), 1619–1632 (2011)
23. Bader, J., Zitzler, E.: HypE: an algorithm for fast hypervolume-based many-objective optimization. Tech. Rep. TIK 286, Computer Engineering and Networks Laboratory, ETH Zurich, Zurich (2008)

24. Baena-García, M., Campo-Ávila, J.D., Fidalgo, R., Bifet, A.: Early drift detection method. In: Procedings of the 4th ECML PKDD International Workshop on Knowledge Discovery From Data Streams (IWKDDS), pp. 77–86. Berlin, Germany (2006)
25. Baker, S.: The identification of the self. Psyc. Rev. **4**(3), 272–284 (1897)
26. Banks, A., Gupta, R.: MQTT Version 3.1.1. http://docs.oasis-open.org/mqtt/mqtt/v3.1.1/os/mqtt-v3.1.1-os.html (2014)
27. Bartolini, D.B., Sironi, F., Maggio, M., Cattaneo, R., Sciuto, D., Santambrogio, M.D.: A Framework for Thermal and Performance Management. In: Proceedings of the Workshop on Managing Systems Automatically and Dynamically (MAD) (2012)
28. Basheer, I.A., Hajmeer, M.: Artificial neural networks: fundamentals, computing, design, and application. Journal of Microbiological Methods **43**(1), 3–31 (2000)
29. Basseur, M., Zitzler, E.: Handling uncertainty in indicator-based multiobjective optimization. International Journal of Computational Intelligence Research **2**(3), 255–272 (2006)
30. Basudhar, A., Dribusch, C., Lacaze, S., Missoum, S.: Constrained efficient global optimization with support vector machines. Structural and Multidisciplinary Optimization **46**(2), 201–221 (2012)
31. Baumann, A., Boltz, M., Ebling, J., Koenig, M., Loos, H.S., Merkel, M., Niem, W., Warzelhan, J.K., Yu, J.: A review and comparison of measures for automatic video surveillance systems. EURASIP Journal on Image and Video Processing **2008**(4) (2008). DOI 10.1155/2008/824726
32. Becker, T., Agne, A., Lewis, P.R., Bahsoon, R., Faniyi, F., Esterle, L., Keller, A., Chandra, A., Jensenius, A.R., Stilkerich, S.C.: EPiCS: Engineering proprioception in computing systems. In: Proceedings of the International Conference on Computational Science and Engineering (CSE), pp. 353–360. IEEE Computer Society (2012)
33. Ben-Hur, A., Weston, J.: A user's guide to support vector machines. Data Mining Techniques for the Life Sciences **609**, 223–239 (2010)
34. Betts, A., Chong, N., Donaldson, A.F., Qadeer, S., Thompson, P.: GPUVerify: a verifier for GPU kernels. In: Proceedings of the ACM International Conference on object-oriented Programming Systems Languages and Applications (OOPSLA) (2012)
35. Beume, N., Naujoks, B., Emmerich, M.: SMS-EMOA: Multiobjective selection based on dominated hypervolume. European Journal on Operational Research **181**(3), 1653–1669 (2007)
36. Bevilacqua, F., Zamborlin, B., Sypniewski, A., Schnell, N., Guédy, F., Rasamimanana, N.: Continuous realtime gesture following and recognition. In: Gesture in embodied communication and human-computer interaction, pp. 73–84. Springer (2010)
37. Biehl, J.T., Adamczyk, P.D., Bailey, B.P.: Djogger: A mobile dynamic music device. In: Proceedings of CHI '06 Extended Abstracts on Human Factors in Computing Systems, pp. 556–561. ACM (2006)
38. Bishop, C.M.: Neural Networks for Pattern Recognition. Oxford University Press, United Kingdom (2005)
39. Bojic, I., Lipic, T., Podobnik, V.: Bio-inspired clustering and data diffusion in machine social networks. In: Computational Social Networks, pp. 51–79. Springer (2012)
40. Bongard, J., Lipson, H.: Evolved machines shed light on robustness and resilience. Proceedings of the IEEE **102**(5), 899–914 (2014)
41. Bongard, J., Zykov, V., Lipson, H.: Resilient machines through continuous self-modeling. Science **314**(5802), 1118–1121 (2006)
42. Borkar, S.: Designing Reliable Systems from Unreliable Components: The Challenges of Transistor Variability and Degradation. IEEE Micro pp. 10–16 (2005)
43. Bouabene, G., Jelger, C., Tschudin, C., Schmid, S., Keller, A., May, M.: The Autonomic Network Architecture (ANA). IEEE Journal on Selected Areas in Communications **28**(1), 4–14 (2010). DOI 10.1109/JSAC.2010.100102
44. Boyd, J.: The Essence of Winning and Losing. http://dnipogo.org/john-r-boyd/ (1996). (Accessed March 8, 2016)
45. Bramberger, M., Doblander, A., Maier, A., Rinner, B., Schwabach, H.: Distributed Embedded Smart Cameras for Surveillance Applications. IEEE Computer **39**(2), 68–75 (2006)

46. Brdiczka, O., Crowley, J.L., Reignier, P.: Learning situation models in a smart home. IEEE Transactions on Systems, Man, and Cybernetics, Part B **39**, 56–63 (2009)
47. Breiman, L.: Bagging predictors. Machine Learning **24**(2), 123–140 (1996)
48. Breiman, L.: Random forests. Machine Learning **45**(1), 5–32 (2001)
49. Brockhoff, D., Zitzler, E.: Improving hypervolume-based multiobjective evolutionary algorithms by using objective reduction methods. In: Proceedings of the 2007 IEEE Congress on Evolutionary Computation, pp. 2086–2093 (2007)
50. Buchanan, J.T.: A naive approach for solving MCDM problems: The GUESS method. Journal of the Operational Research Society **48**(2), 202–206 (1997)
51. Buck, J.: Synchronous rhythmic flashing of fireflies. The Quarterly Review of Biology **13**(3), 301–314 (1938)
52. Buck, J.: Synchronous rhythmic flashing of fireflies II. The Quarterly Review of Biology **63**(3), 265–289 (1988)
53. Burke, E.K., Gendreau, M., Hyde, M., Kendall, G., Ochoa, G., Ozcan, E., Qu, R.: Hyperheuristics: A survey of the state of the art. Journal of the Operational Research Society **206**(1), 241–264 (2013)
54. Buschmann, F., Henney, K., Douglas, S.C.: Pattern-oriented software architecture: On patterns and pattern languages. John Wiley and Sons (2007)
55. Buss, A.H.: Self-consciousness and social anxiety. W. H. Freeman, San Fransisco, CA, USA (1980)
56. Calinescu, R., Ghezzi, C., Kwiatkowska, M., Mirandola, R.: Self-adaptive software needs quantitative verication at runtime. Communications of the ACM **55**(9), 69–77 (2012)
57. Caramiaux, B., Wanderley, M.M., Bevilacqua, F.: Segmenting and parsing instrumentalists' gestures. Journal of New Music Research **41**(1), 13–29 (2012)
58. Carver, C.S., Scheier, M.: Attention and Self-Regulation: A Control-Theory Approach to Human Behavior. Springer (1981)
59. de Castro, L.N.: Fundamentals of natural computing: basic concepts, algorithms, and applications. Chapman & Hall/CRC Computer and Information Sciences (2006)
60. Chandra, A.: A methodical framework for engineering co-evolution for simulating socioeconomic game playing agents. Ph.D. thesis, The University of Birmingham (2011)
61. Chandra, A., Nymoen, K., Volsund, A., Jensenius, A.R., Glette, K., Torresen, J.: Enabling participants to play rhythmic solos within a group via auctions. In: Proceedings of the International Symposium on Computer Music Modeling and Retrieval (CMMR), pp. 674–689 (2012)
62. Chandra, A., Yao, X.: Ensemble learning using multi-objective evolutionary algorithms. Journal of Mathematical Modelling and Algorithms **5**(4), 417–445 (2006)
63. Chang, C., Wawrzynek, J., Brodersen, R.W.: BEE2: a high-end reconfigurable computing system. IEEE Transactions on Design & Test of Computer **22**(2), 114–125 (2005)
64. Chen, J., John, L.K.: Efficient program scheduling for heterogeneous multi-core processors. In: Proceedings of the Design Automation Conference (DAC). ACM (2009)
65. Chen, R., Lewis, P.R., Yao, X.: Temperature management for heterogeneous multi-core FPGAs using adaptive evolutionary multi-objective approaches. In: Proceedings of the International Conference on Evolvable Systems (ICES), pp. 101–108. IEEE (2014)
66. Chen, S., Langner, C.A., Mendoza-Denton, R.: When dispositional and role power fit: implications for self-expression and self-other congruence. Journal of Personality and Social Psychology **96**(3), 710–27 (2009)
67. Chen, T., Bahsoon, R.: Self-adaptive and Sensitivity-aware QoS Modeling for the Cloud. In: Proceedings of the 8th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS), pp. 43–52. IEEE (2013). URL http://dl.acm.org/citation.cfm?id=2487336.2487346
68. Chen, T., Bahsoon, R.: Symbiotic and Sensitivity-aware Architecture for Globally-optimal Benefit in Self-adaptive Cloud. In: Proceedings of the 9th International Symposium on Software Engineering for Adaptive and Self-Managing Systems (SEAMS), pp. 85–94. ACM (2014). DOI 10.1145/2593929.2593931. URL http://doi.acm.org/10.1145/2593929.2593931

69. Chen, T., Bahsoon, R., Yao, X.: Online QoS Modeling in the Cloud: A Hybrid and Adaptive Multi-learners Approach. In: 2014 IEEE/ACM 7th International Conference on Utility and Cloud Computing (UCC), pp. 327–336 (2014)
70. Chen, T., Faniyi, F., Bahsoon, R., Lewis, P.R., Yao, X., Minku, L.L., Esterle, L.: The handbook of engineering self-aware and self-expressive systems. Tech. rep., EPiCS EU FP7 project consortium (2014). URL http://arxiv.org/abs/1409.1793. Available via EPiCS website and arXiv
71. Chen, X., Li, X., Wu, H., Qiu, T.: Real-time Object Tracking via CamShift-based Robust Framework. In: Proceedings of the International Conference on Information Science and Technology (ICIST). IEEE (2012)
72. Chow, G.C.T., Grigoras, P., Burovskiy, P., Luk, W.: An efficient sparse conjugate gradient solver using a Beneš permutation network. In: Proceedings of the 24th International Conference on Field Programmable Logic and Applications, pp. 1–7 (2014)
73. Chow, G.C.T., Tse, A.H.T., Jin, Q., Luk, W., Leong, P.H.W., Thomas, D.B.: A mixed precision Monte Carlo methodology for reconfigurable accelerator systems. In: Proceedings of the ACM/SIGDA 20th International Symposium on Field Programmable Gate Arrays, FPGA 2012, Monterey, California, USA, February 22-24, 2012, pp. 57–66 (2012)
74. Christensen, A.L., O'Grady, R., Dorigo, M.: From fireflies to fault-tolerant swarms of robots. IEEE Transactions on Evolutionary Computation **13**(4), 754–766 (2009)
75. Christensen, E., Curbera, F., Meredith, G., Weerawarana, S.: Web Services Description Language (WSDL) 1.1. World Wide Web Consortium (2001)
76. Chu, F., Zaniolo, C.: Fast and light boosting for adaptive mining of data streams. In: Proceedings of the Eighth Pacific-Asia Knowledge Discovery and Data Mining Conference (PAKDD), pp. 282–292. Sydney (2004)
77. Cichowski, A., Madden, C., Detmold, H., Dick, A., Van den Hengel, A., Hill, R.: Tracking Hand-off in Large Surveillance Networks. In: Proceedings of the International Conference Image and Vision Computing, pp. 276–281. IEEE Computer Society Press (2009). DOI 10.1109/IVCNZ.2009.5378396
78. Claus, C., Boutilier, C.: The Dynamics of Reinforcement Learning in Cooperative Multiagent Systems. In: Proceedings of the Conference on Artificial Intelligence/Innovative Applications of Artificial Intelligence, pp. 746–752. American Association for Artificial Intelligence (1998)
79. Collins, N.: The analysis of generative music programs. Organised Sound **13**, 237–248 (2008)
80. Collins, R.T., Liu, Y., Leordeanu, M.: Online selection of discriminative tracking features. IEEE Transactions on Pattern Analysis and Machine Intelligence **27**(10), 1631–1643 (2005). DOI 10.1109/tpami.2005.205
81. Colorni, A., Dorigo, M., Maniezzo, V., et al.: Distributed optimization by ant colonies. In: Proceedings of the first European conference on artificial life, vol. 142, pp. 134–142. Elsevier (1991)
82. Comaniciu, D., Ramesh, V., Meer, P.: Kernel-based object tracking. IEEE Transactions on Pattern Analysis and Machine Intelligence **25**(5) (2003). DOI 10.1109/tpami.2003.1195991
83. Connors, K.: Chemical kinetics: the study of reaction rates in solution. VCH Publishers (1990)
84. Cox, M.: Metacognition in computation: A selected research review. Artificial Intelligence **169**(2), 104–141 (2005)
85. Cramer, T., Schmidl, D., Klemm, M., an Mey, D.: OpenMP Programming on Intel Xeon Phi Coprocessors: An Early Performance Comparison. In: Proceedings of the Many-core Applications Research Community (MARC) Symposium, pp. 38–44. Aachen, Germany (2012)
86. Crockford, D.: The application/json Media Type for JavaScript Object Notation (JSON). RFC 7159, RFC Editor (2014). URL http://tools.ietf.org/pdf/rfc7159.pdf
87. Curreri, J., Stitt, G., George, A.D.: High-level synthesis of in-circuit assertions for verification, debugging, and timing analysis. International Journal of Reconfigurable Computing **2011**, 1–17 (2011). DOI http://dx.doi.org/10.1155/2011/406857

88. Czajkowski, T.S., Aydonat, U., Denisenko, D., Freeman, J., Kinsner, M., Neto, D., Wong, J., Yiannacouras, P., Singh, D.P.: From OpenCL to high-performance hardware on FPGAs. In: Proceedings of the 22nd International Conference on Field Programmable Logic and Applications (FPL), pp. 531–534. Oslo, Norway (2012)
89. Datta, K., Murphy, M., Volkov, V., Williams, S., Carter, J., Oliker, L., Patterson, D., Shalf, J., Yelick, K.: Stencil computation optimization and auto-tuning on state-of-the-art multicore architectures. In: Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis (SC 2008)., p. 4. IEEE (2008)
90. Davidson, A.A., Owens, J.D.: Toward techniques for auto-tuning GPU algorithms. In: Proceedings of the 10th International Conference on Applied Parallel and Scientific Computing (PARA), Revised Selected Papers, Part II, pp. 110–119. Reykjavík (2010)
91. Day, J.: Patterns in Network Architecture: A Return to Fundamentals. Prentice Hall International (2008)
92. Day, J., Matta, I., Mattar, K.: Networking is IPC: A Guiding Principle to a Better Internet. In: Proceedings of the 2008 ACM CoNEXT Conference, pp. 67:1–67:6 (2008). DOI 10.1145/1544012.1544079. URL http://doi.acm.org/10.1145/1544012.1544079
93. Dean, J., Ghemawat, S.: MapReduce: Simplified Data Processing on Large Clusters. In: Proceedings of the 6th Symposium on Operating System Design and Implementation (OSDI), pp. 137–150. San Francisco, California, USA (2004)
94. Deb, K.: Multi-objective optimization using evolutionary algorithms, vol. 16. John Wiley & Sons, England (2001)
95. Deb, K., Pratap, A., Agarwal, S., Meyarivan, T.: A fast and elitist multiobjective genetic algorithm: NSGA-II. IEEE Transactions on Evolutionary Computation **6**(2), 182–197 (2002)
96. Denholm, S., Inoue, H., Takenaka, T., Luk, W.: Application-specific customisation of market data feed arbitration. In: Proceedings of the International Conference on Field Programmable Technology (ICFPT), pp. 322–325. IEEE (2013)
97. Denholm, S., Inouey, H., Takenakay, T., Becker, T., Luk, W.: Low latency FPGA acceleration of market data feed arbitration. In: Proceedings of the International Conference on Application-Specific Systems, Architectures, and Processors (ASAP), pp. 36–40. IEEE (2014). DOI 10.1109/ASAP.2014.6868628
98. Dennett, D.C.: Consciousness Explained. Penguin Science (1993)
99. Dennis, J.B., Misunas, D.: A preliminary architecture for a basic data flow processor. In: Proceedings of the 2nd Annual Symposium on Computer Architecture, pp. 126–132 (1974)
100. Dieber, B., Simonjan, J., Esterle, L., Rinner, B., Nebehay, G., Pflugfelder, R., Fernandez, G.J.: Ella: Middleware for multi-camera surveillance in heterogeneous visual sensor networks. In: Proceedings of the International Conference on Distributed Smart Cameras (ICDSC) (2013). DOI 10.1109/ICDSC.2013.6778223
101. Dietterich, T.G.: Ensemble methods in machine learning. In: Proceedings of the First International Workshop on Multiple Classifier Systems, Lecture Notes in Computer Science, pp. 1–15. Springer-Verlag (2000)
102. Diguet, J.P., Eustache, Y., Gogniat, G.: Closed-loop–based Self-adaptive Hardware/Software-Embedded Systems: Design Methodology and Smart Cam Case Study. ACM Transactions on Embedded Computing Systems **10**(3), 1–28 (2011)
103. Dinh, M.N., Abramson, D., J. Chao, D.K., Gontarek, A., Moench, B., DeRose, L.: Debugging scientific applications with statistical assertions. Procedia Computer Science **9**(0), 1940––1949 (2012)
104. Dobson, S., Denazis, S., Fernández, A., Gaïti, D., Gelenbe, E., Massacci, F., Nixon, P., Saffre, F., Schmidt, N., Zambonelli, F.: A survey of autonomic communications. ACM Transactions on Autonomous and Adaptive Systems **1**(2), 223–259 (2006)
105. Dobson, S., Sterritt, R., Nixon, P., Hinchey, M.: Fulfilling the vision of autonomic computing. IEEE Computer **43**(1), 35 –41 (2010)
106. Dobzhansky, T., Hecht, M., Steere, W.: On some fundamental concepts of evolutionary biology. Evolutionary Biology **2**, 1–34 (1968)
107. Dorigo, M.: Optimization, learning and natural algorithms. Ph.D. thesis, Politecnico di Milano (1992)

108. Dorigo, M., Blum, C.: Ant colony optimization theory: A survey. Theoretical computer science **344**(2), 243–278 (2005)
109. Dorigo, M., Maniezzo, V., Colorni, A.: Ant system: optimization by a colony of cooperating agents. IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics **26**(1), 29–41 (1996)
110. Dutta, R., Rouskas, G., Baldine, I., Bragg, A., Stevenson, D.: The SILO Architecture for Services Integration, controL, and Optimization for the Future Internet. In: Proceedings of the IEEE International Conference on Communications (ICC), pp. 1899–1904 (2007). DOI 10.1109/ICC.2007.316
111. Duval, S., Wicklund, R.A.: A theory of objective self awareness. Academic Press (1972)
112. Ehrgott, M.: Other Methods for Pareto Optimality. In: Multicriteria Optimization, Lecture Notes in Economics and Mathematical Systems, vol. 491, pp. 77–102. Springer (2000)
113. Eiben, A.E., Smith, J.E.: Introduction to evolutionary computing. Springer (2003)
114. Eigenfeldt, A., Pasquier, P.: Considering vertical and horizontal context in corpus-based generative electronic dance music. In: Proceedings of the Fourth International Conference on Computational Creativity, p. 72 (2013)
115. Eigenfeldt, A., Pasquier, P.: Evolving structures for electronic dance music. In: Proceedings of the 15th Annual Conference on Genetic and Evolutionary Computation (GECCO), pp. 319–326. ACM (2013)
116. Elkhodary, A., Esfahani, N., Malek, S.: FUSION: a framework for engineering self-tuning self-adaptive software systems. In: Proceedings of the eighteenth ACM SIGSOFT International Symposium on Foundations of Software Engineering, pp. 7–16. ACM (2010). DOI 10.1145/1882291.1882296. URL http://doi.acm.org/10.1145/1882291.1882296
117. Elliott, G.T., Tomlinson, B.: PersonalSoundtrack: context-aware playlists that adapt to user pace. In: Proceedings of CHI'06 Extended Abstracts on Human Factors in Computing Systems, pp. 736–741. ACM (2006)
118. Ellis, T., Makris, D., Black, J.: Learning a Multi-camera Topology. In: Proceedings of the Joint International Workshop on Visual Surveillance and Performance Evaluation of Tracking and Surveillance, pp. 165–171. IEEE Computer Society Press (2003)
119. Elwell, R., Polikar, R.: Incremental learning of concept drift in nonstationary environments. IEEE Transactions on Neural Networks **22**, 1517–1531 (2011)
120. Endo, T., Matsuoka, S.: Massive supercomputing coping with heterogeneity of modern accelerators. In: Proceedings of the 22nd IEEE International Symposium on Parallel and Distributed Processing (IPDPS), pp. 1–10 (2008)
121. Erdem, U.M., Sclaroff, S.: Look there! Predicting Where to Look for Motion in an Active Camera Network. In: Proceedings of the IEEE Conference on Advanced Video and Signal-based Surveillance, pp. 105–110. Como, Italy (2005)
122. Esterle, L., Lewis, P.R., Bogdanski, M., Rinner, B., Yao, X.: A socio-economic approach to online vision graph generation and handover in distributed smart camera networks. In: Proceedings of the International Conference on Distributed Smart Cameras (ICDSC), pp. 1–6. IEEE (2011). DOI 10.1109/ICDSC.2011.6042902
123. Esterle, L., Lewis, P.R., Caine, H., Yao, X., Rinner, B.: CamSim: A distributed smart camera network simulator. In: Proceedings of the International Conference on Self-Adaptive and Self-Organizing Systems Workshops, pp. 19–20. IEEE Computer Society Press (2013). DOI 10.1109/SASOW.2013.11
124. Esterle, L., Lewis, P.R., Rinner, B., Yao, X.: Improved adaptivity and robustness in decentralised multi-camera networks. In: Proceedings of the International Conference on Distributed Smart Cameras, pp. 1–6. ACM (2012)
125. Esterle, L., Lewis, P.R., Yao, X., Rinner, B.: Socio-economic vision graph generation and handover in distributed smart camera networks. ACM Transactions on Sensor Networks **10**(2), 20:1–20:24 (2014). DOI 10.1145/2530001
126. Eugster, P.T., Felber, P.A., Guerraoui, R., Kermarrec, A.M.: The Many Faces of Publish/Subscribe. ACM Computing Surveys **35**(2), 114–131 (2003)

127. Faniyi, F., Lewis, P.R., Bahsoon, R., Xao, X.: Architecting self-aware software systems. In: Proceedings of the IEEE/IFIP Conference on Software Architecture (WICSA), pp. 91–94. IEEE (2014)
128. Farrell, R., Davis, L.S.: Decentralized discovery of camera network topology. In: Proceedings of the International Conference on Distributed Smart Cameras, pp. 1–10. IEEE Computer Society Press (2008). DOI 10.1109/ICDSC.2008.4635696
129. Fels, S., Hinton, G.: Glove-talk: A neural network interface between a data-glove and a speech synthesizer. IEEE Transactiona on Neural Networks **4**(1), 2–8 (1993)
130. Feng, W.: Making a case for efficient supercomputing. ACM Queue **1**(7), 54–64 (2003)
131. Fenigstein, A., Scheier, M.F., Buss, A.H.: Public and private self-consciousness: Assessment and theory. Journal of Consulting and Clinical Psychology **43**(4), 522–527 (1975)
132. Fern, A., Givan, R.: Online ensemble learning: An empirical study. Machine Learning **53**(1–2), 71–109 (2003)
133. Fette, B.: Cognitive radio technology. Academic Press (2009)
134. Fiebrink, R., Trueman, D., Cook, P.R.: A meta-instrument for interactive, on-the-fly machine learning. In: Proceedings of the International Conference on New Interfaces for Musical Expression. Pittsburgh (2009)
135. Fielding, R.T., Taylor, R.N.: Principled design of the modern web architecture. ACM Transactions on Internet Technology **2**(2), 115–150 (2002). DOI 10.1145/514183.514185. URL http://doi.acm.org/10.1145/514183.514185
136. Freund, Y., Schapire, R.E.: Experiments with a new boosting algorithm. In: Proceedings of the 13th International Conference on Machine Learning, pp. 148–156 (1996)
137. Froming, W.J., Walker, G.R., Lopyan, K.J.: Public and private self-awareness: When personal attitudes conflict with societal expectations. Journal of Experimental Social Psychology **18**(5), 476 – 487 (1982). DOI 10.1016/0022-1031(82)90067-1
138. Fu, H., Sendhoff, B., Tang, K., Yao, X.: Finding robust solutions to dynamic optimization problems. In: Proceedings of the 16th European conference on Applications of Evolutionary Computation (EvoApplications), pp. 616–625 (2013)
139. Funie, A., Salmon, M., Luk, W.: A hybrid genetic-programming swarm-optimisation approach for examining the nature and stability of high frequency trading strategies. In: Proceedings of the 13th International Conference on Machine Learning and Applications (ICMLA), pp. 29–34. Detroit, USA (2014). DOI 10.1109/ICMLA.2014.11. URL http://dx.doi.org/10.1109/ICMLA.2014.11
140. Gallup, G.G.: Chimpanzees: self-recognition. Science (1970)
141. Gama, J., Medas, P., Castillo, G., Rodrigues, P.: Learning with drift detection. In: Proceedings of the 7th Brazilian Symposium on Artificial Intelligence (SBIA) - Lecture Notes in Computer Science, vol. 3171, pp. 286–295. Springer, São Luiz do Maranhão, Brazil (2004)
142. Gao, J., Fan, W., Han, J.: On appropriate assumptions to mine data streams: Analysis and practice. In: Proceedings of the Seventh IEEE International Conference on Data Mining (ICDM), pp. 143–152 (2007)
143. Garlan, D., Cheng, S.W., Huang, A.C., Schmerl, B., Steenkiste, P.: Rainbow: architecture-based self-adaptation with reusable infrastructure. IEEE Computer **37**(10), 46–54 (2004)
144. Gelenbe, E., Loukas, G.: A self-aware approach to denial of service defence. Computer Networks **51**(5), 1299–1314 (2007)
145. Goto, M.: Active music listening interfaces based on signal processing. In: Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, vol. 4, pp. 1441–1444 (2007)
146. Gouin-Vallerand, C., Abdulrazak, B., Giroux, S., Mokhtari, M.: Toward autonomic pervasive computing. In: Proceedings of the 10th International Conference on Information Integration and Web-based Applications & Services, iiWAS '08, pp. 673–676. ACM, New York, NY, USA (2008)
147. Goukens, C., Dewitte, S., Warlop, L.: Me, myself, and my choices: The influence of private self-awareness on preference-behavior consistency. Tech. rep., Katholieke Universiteit Leuven (2007)

148. Grabner, H., Bischof, H.: On-line Boosting and Vision. In: Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp. 260–267 (2006)
149. Grabner, H., Leistner, C., Bischof, H.: Semi-supervised on-line Boosting for Robust Tracking. In: Proceedings of the European Conference on Computer Vision, Lecture Notes in Computer Science, vol. 5302, pp. 234–247 (2008)
150. Group, K.: The OpenCL specification, version: 1.1. http://www.khronos.org/registry/cl/specs/opencl-1.1.pdf. (Accessed March 8, 2016)
151. Gudger, E.W.: A historical note on the synchronous flashing of fireflies. Science **50**(1286), 188–190 (1919)
152. Gudgin, M., Hadley, M., Mendelsohn, N., Moreau, J.J., Nielsen, H.F., Karmarkar, A., Lafon, Y.: SOAP Version 1.2. World Wide Web Consortium (2007)
153. Guo, C., Luk, W.: Accelerating Maximum Likelihood Estimation for Hawkes Point Processes. In: Proceedings of the International Conference on Field Programmable Logic and Applications (FPL), pp. 1–6. IEEE (2013)
154. Guo, C., Luk, W.: Accelerating parameter estimation for multivariate self-exciting point processes. In: Proceedings of the International Symposium on Field-Programmable Gate Arrays (FPGA), pp. 181–184. ACM (2014). DOI 10.1145/2554688.2554765
155. Haikonen, P.O.: Reflections of consciousness: The mirror test. In: Proceedings of the AAAI Fall Symposium on Consciousness and Artificial Intelligence, pp. 67–71 (2007)
156. Hamid, R., Maddi, S., Johnson, A., Bobick, A., Essa, I., Isbell, C.: A novel sequence representation for unsupervised analysis of human activities. Artificial Intelligence **173**(14), 1221–1244 (2009). DOI DOI: 10.1016/j.artint.2009.05.002
157. Hansen, N.: The CMA evolution strategy: A comparing review. In: J. Lozano, P. Larrañaga, I. Inza, E. Bengoetxea (eds.) Towards a New Evolutionary Computation, *Studies in Fuzziness and Soft Computing*, vol. 192, pp. 75–102. Springer Berlin Heidelberg (2006)
158. Happe, M., Agne, A., Plessl, C.: Measuring and Predicting Temperature Distributions on FPGAs at Run-Time. In: Proceedings of the International Conference on Reconfigurable Computing and FPGAs (ReConFig), pp. 55–60. IEEE Computer Society (2011). DOI 10.1109/ReConFig.2011.59
159. Happe, M., Huang, Y., Keller, A.: Dynamic Protocol Stacks in Smart Camera Networks. In: Proceedings of the International Conference on Reconfigurable Computing and FPGAs (ReConFig), pp. 1–6. IEEE (2014)
160. Happe, M., Traber, A., Keller, A.: Preemptive Hardware Multitasking in ReconOS. In: Proceedings of the International Symposium on Applied Reconfigurable Computing (ARC), Springer (2015)
161. Hart, J.W., Scassellati, B.: Robotic self-modeling. In: J. Pitt (ed.) The Computer After Me, pp. 207–218. Imperial College Press / World Scientific Book (2014)
162. Heath, D., Jarrow, R., Morton, A.: Bond pricing and the term structure of interest rates: A new methodology for contingent claims valuation. Econometrica **60**(1), 77–105 (1992)
163. Hernandez, H., Blum, C.: Distributed graph coloring in wireless ad hoc networks: A light-weight algorithm based on Japanese tree frogs' calling behaviour. In: Proceedings of the 4th Joint IFIP Wireless and Mobile Networking Conference (WMNC), pp. 1–7 (2011)
164. Herzen, B.V.: Signal Processing at 250 MHz Using High-Performance FPGAs. In: Proceedings of the ACM Fifth International Symposium on Field-programmable Gate Arrays, pp. 62–68 (1997)
165. Ho, T.K.: The Random Subspace Method for Constructing Decision Forests. IEEE Transactions on Pattern Analysis and Machine Intelligence **20**(8), 832–844 (1998)
166. Ho, T.K., Hull, J.J., Srihari, S.N.: Decision Combination in Multiple Classifier Systems. IEEE Transactions on Pattern Analysis and Machine Intelligence **16**(1), 66–75 (1994)
167. Ho, T.S.Y., Lee, S.B.: Term Structure Movements and Pricing Interest Rate Contingent Claims. Journal of Finance **41**(5), 1011–1029 (1986)
168. Hoare, C.A.R.: An axiomatic basis for computer programming. Communications of the ACM **12**(10), 576–580 (1969)

169. Hockman, J.A., Wanderley, M.M., Fujinaga, I.: Real-time phase vocoder manipulation by runner's pace. In: Proceedings of the International Conference on New Interfaces for Musical Expression (2009)
170. Hoffmann, H., Eastep, J., Santambrogio, M., Miller, J., Agarwal, A.: Application heartbeats for software performance and health. In: ACM SIGPLAN Notices, vol. 45, pp. 347–348. ACM (2010)
171. Hoffmann, H., Eastep, J., Santambrogio, M.D., Miller, J.E., Agarwal, A.: Application Heartbeats: A Generic Interface for Specifying Program Performance and Goals in Autonomous Computing Environments. In: Proceedings of the International Conference on Autonomic Computing (ICAC) (2010)
172. Hoffmann, H., Holt, J., Kurian, G., Lau, E., Maggio, M., Miller, J.E., Neuman, S.M., Sinangil, M., Sinangil, Y., Agarwal, A., Chandrakasan, A.P., Devadas, S.: Self-aware computing in the Angstrom processor. In: Proceedings of the 49th Annual Design Automation Conference, DAC '12, pp. 259–264. ACM, New York, NY, USA (2012)
173. Hoffmann, H., Maggio, M., Santambrogio, M.D., Leva, A., Agarwal, A.: SEEC: A general and extensible framework for self-aware computing. Tech. Rep. MIT-CSAIL-TR-2011-046, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology (2011)
174. Holland, B., George, A.D., Lam, H., Smith, M.C.: An analytical model for multilevel performance prediction of Multi-FPGA systems. ACM Transactions on Reconfigurable Technology and Systems **4**(3), 27–28 (2011)
175. Holland, O., Goodman, R.B.: Robots with internal models: A route to machine consciousness? Journal of Consciousness Studies **10**(4), 77–109 (2003)
176. Holopainen, R.: Self-organised sound with autonomous instruments: Aesthetics and experiments. Ph.D. thesis, University of Oslo (2012)
177. Hölzl, M., Wirsing, M.: Towards a system model for ensembles. In: Formal Modeling: Actors, Open Systems, Biological Systems, pp. 241–261. Springer (2011)
178. Hölzl, M., Wirsing, M.: Issues in engineering self-aware and self-expressive ensembles. In: J. Pitt (ed.) The Computer After Me, pp. 37–54. Imperial College Press/World Scientific Book (2014)
179. Horn, J., Nafpliotis, N., Goldberg, D.E.: A niched Pareto genetic algorithm for multiobjective optimization. In: Proceedings of the 1st IEEE Conference on Evolutionary Computation, IEEE World Congress on Computational Intelligence, pp. 82–87 (1994)
180. Horn, P.: Autonomic computing: IBM's perspective on the state of information technology. Armonk, NY, USA. International Business Machines Corporation. (2001)
181. Hosseini, M.J., Ahmadi, Z., Beigy, H.: Using a classifier pool in accuracy based tracking of recurring concepts in data stream classification. Evolving Systems **4**(1), 43–60 (2013)
182. Hsu, C.H., Feng, W.C.: Reducing overheating-induced failures via performance-aware CPU power management. In: Proceedings of the 6th International Conference on Linux Clusters: The HPC Revolution (2005)
183. Hu, F., Evans, J.J.: Power and environment aware control of Beowulf clusters. Cluster Computing **12**, 299–308 (2009)
184. Hu, W., Tan, T., Wang, L., Maybank, S.: A Survey on Visual Surveillance of Object Motion and Behaviors. IEEE Transactions on Systems, Man and Cybernetics, Part C **34**(3), 334–352 (2004)
185. Huang, T., Russell, S.: Object Identification in a Bayesian Context. In: Proceedings of the International Joint Conference on Artificial Intelligence, pp. 1276–1283 (1997)
186. Huebscher, M., McCann, J.: Simulation Model for Self-Adaptive Applications in Pervasive Computing. In: Proceedings of the 15th International Workshop on Database and Expert Systems Applications, pp. 694–698. IEEE Computer Society (2004)
187. Hume, D.: A Treatise of Human Nature. Gutenberg eBook (1739). URL http://www.gutenberg.org/ebooks/4705. (Accessed March 8, 2016)
188. Hunkeler, U., Truong, H.L., Stanford-Clark, A.: MQTT-S–A publish/subscribe protocol for Wireless Sensor Networks. In: Proceedings of the Third International Conference on Communication Systems Software and Middleware and Workshops (COMSWARE), pp. 791–798. IEEE (2008)

189. Hunt, A., Wanderley, M.M., Paradis, M.: The importance of parameter mapping in electronic instrument design. In: Proceedings of the International Conference on New Interfaces for Musical Expression, pp. 1–6. National University of Singapore (2002)
190. IBM: An architectural blueprint for autonomic computing (2003). URL http://www-03.ibm.com/autonomic/pdfs/AC Blueprint White Paper V7.pdf. (Accessed March 8, 2016)
191. Iglesia, D.: MobMuPlat (iOS application). Iglesia Intermedia (2013)
192. Intel: Sophisticated library for vector parallelism. http://software.intel.com/en-us/articles/intel-array-building-blocks/. (Accessed March 8, 2016)
193. Investigating RINA as an Alternative to TCP/IP. URL http://irati.eu. (Accessed March 8, 2016)
194. Ishibuchi, H., Murata, T.: A multiobjective genetic local search algorithm and its application to flowshop scheduling. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews **28**(3), 392–403 (1998)
195. Ishibuchi, H., Tsukamoto, N., Nojima, Y.: Iterative approach to indicator-based multiobjective optimization. In: Proceedings of the IEEE Congress on Evolutionary Computation, pp. 3967–3974 (2007)
196. Ishibuchi, H., Tsukamoto, N., Nojima, Y.: Evolutionary many-objective optimization. In: Proceedings of the 3rd International Workshop on Genetic and Evolving Systems (GEFS), pp. 47–52. IEEE (2008)
197. James, W.: The principles of psychology. Henry Holt & Co. (1890)
198. Janusevskis, J., Riche, R.L., Ginsbourger, D., Girdziusas, R.: Expected Improvements for the Asynchronous Parallel Global Optimization of Expensive Functions: Potentials and Challenges. In: Y. Hamadi, M. Schoenauer (eds.) Learning and Intelligent Optimization, pp. 413–418. Springer (2012)
199. Javed, O., Khan, S., Rasheed, Z., Shah, M.: Camera Handoff: Tracking in Multiple Uncalibrated Stationary Cameras. In: Proceedings of the Workshop on Human Motion, pp. 113–118. IEEE Computer Society Press (2000). DOI 10.1109/HUMO.2000.897380
200. Javed, O., Rasheed, Z., Shafique, K., Shah, M.: Tracking across Multiple Cameras Disjoint Views. In: Proceedings of IEEE International Conference on Computer Vision, p. 952–957 (2003)
201. Jia, J., Veeravalli, B., Ghose, D.: Adaptive load distribution strategies for divisible load processing on resource unaware multilevel tree networks. IEEE Transactions on Computers **56**(7), 999–1005 (2007)
202. Jin, Q., Becker, T., Luk, W., Thomas, D.: Optimising explicit finite difference option pricing for dynamic constant reconfiguration. In: Proceedings of the International Conference on Field Programmable Logic and Applications (FPL), pp. 165–172 (2012)
203. Jin, Y., Olhofer, M., Sendhoff, B.: A framework for evolutionary optimization with approximate fitness functions. IEEE Transactions on Evolutionary Computation **6**(5), 481–494 (2002)
204. Jones, D.R., Schonlau, M., Welch, W.J.: Efficient global optimization of expensive black-box functions. Journal of Global Optimization **13**(4), 455–492 (1998)
205. Jones, P., Cho, Y., Lockwood, J.: Dynamically optimizing FPGA applications by monitoring temperature and workloads. In: Proceedings of the International Conference on VLSI Design (VLSID). IEEE (2007)
206. Kalal, Z., Mikolajczyk, K., Matas, J.: Tracking-Learning-Detection. IEEE Transactions on Pattern Analysis and Machine Intelligence **34**(7), 1409–1422 (2012)
207. Kalman, R.E.: A New Approach to Linear Filtering and Prediction Problems. Journal of Fluids Engineering **82**(1), 35–45 (1960)
208. Kamil, S., Chan, C., Oliker, L., Shalf, J., Williams, S.: An auto-tuning framework for parallel multicore stencil computations. In: Proceedings of the IEEE International Symposium on Parallel & Distributed Processing (IPDPS), pp. 1–12 (2010)
209. Kang, J., Cohen, I., Medioni, G.: Continuous Tracking within and across Camera Streams. In: Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, pp. 267–272 (2003)

210. Kant, I.: The critique of pure reason. Gutenberg eBook (1781). URL http://www.gutenberg.org/ebooks/4280. Digital edition 2003 (Accessed March 8, 2016)
211. Kela, J., Korpipää, P., Mäntyjärvi, J., Kallio, S., Savino, G., Jozzo, L., Marca, D.: Accelerometer-based gesture control for a design environment. Personal and Ubiquitous Computing **10**(5), 285–299 (2006)
212. Keller, A., Borkmann, D., Neuhaus, S., Happe, M.: Self-Awareness in Computer Networks. International Journal of Reconfigurable Computing pp. 1–10 (2014). DOI 10.1155/2014/692076
213. Kephart, J.O., Chess, D.M.: The Vision of Autonomic Computing. IEEE Computer **36**(1), 41–50 (2003)
214. Kettnaker, V., Zabith, R.: Bayesian Multi-Camera Surveillance. In: Proceedings of the International Conference on Computer Vision and Pattern Recognition, pp. 117–123 (1999)
215. Khan, M.I., Rinner, B.: Energy-aware task scheduling in wireless sensor networks based on cooperative reinforcement learning. In: Proceedings of the International Conference on Communications Workshops (ICCW). IEEE (2014). DOI 10.1109/ICCW.2014.6881310
216. Khare, V., Yao, X., Deb, K.: Performance scaling of multi-objective evolutionary algorithms. In: Evolutionary Multi-Criterion Optimization, Lecture Notes in Computer Science, vol. 2632, pp. 376–390. Springer (2003)
217. Kim, H.S., Sherman, D.K.: Express yourself: Culture and the effect of self-expression on choice. Journal of Personality and Social Psychology **92**(1), 1–11 (2007). DOI 10.1037/0022-3514.92.1.1
218. Kim, J., Seo, S., Lee, J., Nah, J., Jo, G., Lee, J.: OpenCL as a unified programming model for heterogeneous CPU/GPU clusters. In: Proceedings of the 17th ACM SIGPLAN Symposium on Principles and Practice of Parallel Programming (PPOPP), pp. 299–300 (2012)
219. Kittler, J., Hatef, M., Duin, R.P., Matas, J.: On combining classifiers. IEEE Transactions on Pattern Analysis and Machine Intelligence **20**(3), 226–239 (1998)
220. Klinglmayr, J., Bettstetter, C.: Self-organizing synchronization with inhibitory-coupled oscillators: Convergence and robustness. ACM Transactions on Autonomous and Adaptive Systems **7**(3), 30:1–30:22 (2012)
221. Klinglmayr, J., Kirst, C., Bettstetter, C., Timme, M.: Guaranteeing global synchronization in networks with stochastic interactions. New Journal of Physics **14**(7), 1–13 (2012)
222. Knutzen, H., Nymoen, K., Torresen, J.: PheroMusic [iOS application]. URL http://itunes.apple.com/app/pheromusic/id910100415
223. Kolter, J.Z., Maloof, M.A.: Dynamic weighted majority: An ensemble method for drifting concepts. Journal of Machine Learning Research **8**, 2755–2790 (2007)
224. Koski, J., Silvennoinen, R.: Norm methods and partial weighting in multicriterion optimization of structures. International Journal for Numerical Methods in Engineering **24**(6), 1101–1121 (1987)
225. Kramer, J., Magee, J.: Self-managed systems: an architectural challenge. In: Future of Software Engineering (FoSE), pp. 259–268. IEEE (2007)
226. Krishnamoorthy, S., Baskaran, M., Bondhugula, U., Ramanujam, J., Rountev, A., Sadayappan, P.: Effective automatic parallelization of stencil computations. In: Proceedings of the 28th ACM SIGPLAN Conference on Programming Language Design and Implementation, pp. 235–244 (2007)
227. Kuhn, H.W., Yaw, B.: The Hungarian Method for the Assignment Problem. Naval Research Logistics Quarterly pp. 83–97 (1955)
228. Kuncheva, L.I.: A theoretical study on six classifier fusion strategies. IEEE Transactions on Pattern Analysis and Machine Intelligence **24**(2), 281–286 (2002)
229. Kurek, M., Becker, T., Chau, T.C., Luk, W.: Automating Optimization of Reconfigurable Designs. In: Proceedings of the International Symposium on Field-Programmable Custom Computing Machines (FCCM), pp. 210–213. IEEE (2014). DOI 10.1109/FCCM.2014.65
230. Kurek, M., Becker, T., Luk, W.: Parametric Optimization of Reconfigurable Designs Using Machine Learning. In: Proceedings of the International Conference on Reconfigurable Computing: Architectures, Tools and Applications (ARC), *Lecture Notes in Computer Science*, vol. 7806, pp. 134–145. Springer (2013)

231. Legrain, L., Cleeremans, A., Destrebecqz, A.: Distinguishing three levels in explicit self-awareness. Consciousness and Cognition **20**, 578–585 (2011)
232. Legrand, D.: Pre-reflective self-as-subject from experiential and empirical perspectives. Consciousness and Cognition **16**(3), 583–599 (2007)
233. Leidenfrost, R., Elmenreich, W.: Firefly clock synchronization in an 802.15. 4 wireless network. EURASIP Journal on Embedded Systems **2009**, 7:1–7:17 (2009)
234. Leland, W., Taqqu, M., Willinger, W., Wilson, D.: On the self-similar nature of ethernet traffic (extended version). IEEE/ACM Transactions on Networking **2**(1), 1–15 (1994). DOI 10.1109/90.282603
235. Leutenegger, S., Chli, M., Siegwart, R.Y.: BRISK: Binary robust invariant scalable keypoints. In: Proceedings of the International Conference on Computer Vision, pp. 2548–2555. IEEE (2011). DOI 10.1109/iccv.2011.6126542
236. Lewis, P.R., Chandra, A., Faniyi, F., Glette, K., Chen, T., Bahsoon, R., Torresen, J., Yao, X.: Architectural aspects of self-aware and self-expressive computing systems: From psychology to engineering. IEEE Computer **48**(8), 62–70 (2015)
237. Lewis, P.R., Chandra, A., Parsons, S., Robinson, E., Glette, K., Bahsoon, R., Torresen, J., Yao, X.: A Survey of Self-Awareness and Its Application in Computing Systems. In: Proceedings of the International Conference on Self-Adaptive and Self-Organizing Systems Workshops (SASOW), pp. 102–107. IEEE Computer Society, Ann Arbor, MI, USA (2011)
238. Lewis, P.R., Esterle, L., Chandra, A., Rinner, B., Torresen, J., Yao, X.: Static, Dynamic, and Adaptive Heterogeneity in Distributed Smart Camera Networks. ACM Transactions on Autonomous and Adaptive Systems **10**(2), 8:1–8:30 (2015). DOI 10.1145/2764460
239. Lewis, P.R., Esterle, L., Chandra, A., Rinner, B., Yao, X.: Learning to be Different: Heterogeneity and Efficiency in Distributed Smart Camera Networks. In: Proceedings of the International Conference on Self-Adaptive and Self-Organizing Systems (SASO), pp. 209–218. IEEE Computer Society Press (2013). DOI 10.1109/SASO.2013.20
240. Lewis, P.R., Marrow, P., Yao, X.: Resource Allocation in Decentralised Computational Systems: An Evolutionary Market Based Approach. Autonomous Agents and Multi-Agent Systems **21**(2), 143–171 (2010)
241. Lewis, P.R., Platzner, M., Yao, X.: An outlook for self-awareness in computing systems. Awareness Magazine (2012). DOI 10.2417/3201203.004093
242. Li, B., Li, J., Tang, K., Yao, X.: An improved Two Archive Algorithm for Many-Objective Optimization. In: Proceedings of the IEEE Congress on Evolutionary Computation (CEC), pp. 2869–2876 (2014)
243. Li, G., Gopalakrishnan, G.: Scaleable SMT-based verification of GPU kernel functions. In: Proceedings of the Eighteenth International Symposium on the Foundations of Software Engineering (FSE-18) (2010)
244. Li, H., Zhang, Q.: Multiobjective optimization problems with complicated Pareto sets, MOEA/D and NSGA-II. IEEE Transactions on Evolutionary Computation **13**(2), 284–302 (2009)
245. Li, Y., Bhanu, B.: Utility-based Camera Assignment in a Video Network: A Game Theoretic Framework. Sensors Journal **11**(3), 676–687 (2011)
246. Liang, C.J.M., Liu, J., Luo, L., Terzis, A., Zhao, F.: RACNet: A High-Fidelity Data Center Sensing Network. Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems pp. 15–28 (2009)
247. Liu, J., Zhong, L., Wickramasuriya, J., Vasudevan, V.: uWave: Accelerometer-based personalized gesture recognition and its applications. Pervasive and Mobile Computing **5**(6), 657–675 (2009)
248. Liu, Y., Yao, X.: Ensemble learning via negative correlation. Neural Networks **12**(10), 1399–1404 (1999)
249. Lübbers, E., Platzner, M.: Cooperative multithreading in dynamically reconfigurable systems. In: Proceedings of the International Conference on Field Programmable Logic and Applications (FPL), pp. 1–4. IEEE (2009)
250. Lübbers, E., Platzner, M.: ReconOS: Multithreaded programming for reconfigurable computers. ACM Transactions on Embedded Computing Systems **9** (2009)

251. Lucas, B.D., Kanade, T.: An iterative image registration technique with an application to stereo vision. In: Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI), pp. 674–679 (1981)
252. Maggio, M., Hoffmann, H., Santambrogio, M.D., Agarwal, A., Leva, A.: A comparison of autonomic decision making techniques. Tech. Rep. MIT-CSAIL-TR-2011-019, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology (2011)
253. Makris, D., Ellis, T., Black, J.: Bridging the Gaps between Cameras. In: Proceedings of Conference on Computer Vision and Pattern Recognition, vol. 2 (2004)
254. Marler, R.T., Arora, J.S.: Function-transformation methods for multi-objective optimization. Engineering Optimization **37**(6), 551–570 (2005)
255. Marrow, P.: Nature-inspired computing technology and applications. BT Technology Journal **18**(4), 13–23 (2000)
256. Marsaglia, G., Bray, T.A.: A convenient method for generating normal variables. SIAM Review **6**(3), 260–264 (1964)
257. Masahiro, N., Takaesu, H., Demachi, H., Oono, M., Saito, H.: Development of an automatic music selection system based on runner's step frequency. In: Proceedings of the 2008 International Conference on Music Information Retrieval, pp. 193–8 (2008)
258. Massie, M.L., Chun, B.N., Culler, D.E.: The Ganglia distributed monitoring system: design, implementation, and experience. Parallel Computing **30**, 817–840 (2004)
259. Mathar, R., Mattfeldt, J.: Pulse-coupled decentral synchronization. SIAM Journal on Applied Mathematics **56**(4), 1094–1106 (1996)
260. Max [computer software]. URL http://cycling74.com. (Accessed March 8, 2016)
261. McKay, M.D., Beckman, R.J., Conover, W.J.: A comparison of three methods for selecting values of input variables in the analysis of output from a computer code. Technometrics pp. 55–61 (2000)
262. Mehta, N.R., Medvidovic, N.: Composing architectural styles from architectural primitives. In: Proceedings of the European Software Engineering Conference and ACM SIGSOFT Symposium on the Foundations of Software Engineering, pp. 347–350 (2003). URL http://dblp.uni-trier.de/db/conf/sigsoft/fse2003.html#MehtaM03
263. Menasce, D.A., Sousa, J.a.P., Malek, S., Gomaa, H.: QoS Architectural Patterns for Self-architecting Software Systems. In: Proceedings of the 7th International Conference on Autonomic Computing (ICAC), pp. 195–204. ACM (2010). DOI 10.1145/1809049.1809084
264. Metcalfe, J., Shimamura, A.P. (eds.): Metacognition: Knowing about knowing. MIT Press, Cambridge, MA, USA (1994)
265. Michalski, R.S.: A Theory and Methodology of Inductive Learning. In: Machine Learning, Symbolic Computation, pp. 83–134. Springer Berlin Heidelberg (1983)
266. Miettinen, K., Mäkelä, M.M.: Interactive bundle-based method for nondifferentiable multiobjective optimization: nimbus. Optimization Journal **34**(3), 231–246 (1995)
267. Minku, L.L.: Online ensemble learning in the presence of concept drift. Ph.D. thesis, School of Computer Science, University of Birmingham, Birmingham, UK (2010)
268. Minku, L.L., Yao, X.: DDD: A new ensemble approach for dealing with concept drift. IEEE Transactions on Knowledge and Data Engineering **24**(4), 619–633 (2012)
269. Minku, L.L., Yao, X.: Software Effort Estimation as a Multi-objective Learning Problem. ACM Transactions on Software Engineering and Methodology **22**(4), 35:1–32 (2013)
270. Miranda, E.R., Wanderley, M.: New Digital Musical Instruments: Control and Interaction Beyond the Keyboard. A-R Editions, Inc., Middleton, WI (2006)
271. Mirollo, R.E., Strogatz, S.H.: Synchronization of pulse-coupled biological oscillators. SIAM Journal on Applied Mathematics **50**(6), 1645–1662 (1990)
272. Mitchell, M.: Self-awareness and control in decentralized systems. In: Proceedings of the AAAI Spring Symposium on Metacognition in Computation (2005). Available at http://www.cs.pdx.edu/ mm/self-awareness.pdf
273. Modler, P.: Neural networks for mapping hand gestures to sound synthesis parameters, vol. 18, p. 14. IRCAM — Centre Pompidou (2000)

274. Moens, B., van Noorden, L., Leman, M.: D-Jogger: Syncing music with walking. In: Proceedings of the Sound and Music Computing Conference, pp. 451–456. Barcelona, Spain (2010)
275. Morin, A.: Levels of consciousness and self-awareness: A comparison and integration of various neurocognitive views. Consciousness and Cognition **15**(2), 358–71 (2006)
276. Morin, A., Everett, J.: Conscience de soi et langage interieur: Quelques speculations. [Self-awareness and inner speech: Some speculations]. Philosophiques **XVII**(2), 169–188 (1990)
277. Müller-Schloer, C., Schmeck, H., Ungerer, T.: Organic computing: a paradigm shift for complex systems. Springer (2011)
278. Nakashima, H., Aghajan, H., Augusto, J.C.: Handbook of ambient intelligence and smart environments. Springer (2009)
279. Narukawa, K., Tanigaki, Y., Ishibuchi, H.: Evolutionary many-objective optimization using preference on hyperplane. In: Proceedings of the 2014 Conference on Genetic and Evolutionary Computation Companion, pp. 91–92. ACM (2014)
280. Natarajan, P., Atrey, P.K., Kankanhalli, M.: Multi-camera coordination and control in surveillance systems: A survey. ACM Transactions on Multimedia Computing, Communications and Applications **11**(4), 57:1–57:30 (2015). DOI 10.1145/2710128
281. Nebehay, G., Chibamu, W., Lewis, P.R., Chandra, A., Pflugfelder, R., Yao, X.: Can diversity amongst learners improve online object tracking? In: Z.H. Zhou, F. Roli, J. Kittler (eds.) Multiple Classifier Systems, *Lecture Notes in Computer Science*, vol. 7872, pp. 212–223. Springer (2013). DOI 10.1007/978-3-642-38067-9_19
282. Nebehay, G., Pflugfelder, R.: Consensus-based matching and tracking of keypoints for object tracking. In: Proceedings of the Winter Conference on Applications of Computer Vision (WACV). IEEE (2014)
283. Nebro, A.J., Luna, F., Alba, E., Beham, A., Dorronsoro, B.: AbYSS: adapting scatter search for multiobjective optimization. Tech. Rep. ITI-2006-2, Departamento de Lenguajes y Ciencias de la Computación, University of Málaga, Malaga (2006)
284. Neisser, U.: The Roots of Self-Knowledge: Perceiving Self, It, and Thou. Annals of the NY AoS. **818**, 19–33 (1997)
285. netem. URL http://www.linuxfoundation.org/collaborate/workgroups/networking/netem. (Accessed March 8, 2016)
286. Nguyen, A., Satish, N., Chhugani, J., Kim, C., Dubey, P.: 3.5-D blocking optimization for stencil computations on modern CPUs and GPUs. In: Proceedings of the ACM/IEEE International Conference for High Performance Computing, Networking, Storage and Analysis, pp. 1–13 (2010)
287. Niezen, G., Hancke, G.P.: Evaluating and optimising accelerometer-based gesture recognition techniques for mobile devices. In: Proceedings of AFRICON, pp. 1–6. IEEE (2009)
288. Nishida, K.: Learning and detecting concept drift. Ph.D. thesis, Hokkaido University (2008). URL http://lis2.huie.hokudai.ac.jp/ knishida/paper/nishida2008-dissertation.pdf
289. Nishida, K., Yamauchi, K.: Detecting concept drift using statistical testing. In: Proceedings of the Tenth International Conference on Discovery Science (DS) - Lecture Notes in Artificial Intelligence, vol. 3316, pp. 264–269. Sendai, Japan (2007)
290. Niu, X., Chau, T.C.P., Jin, Q., Luk, W., Liu, Q.: Automating elimination of idle functions by run-time reconfiguration. In: Proceedings of the 21st IEEE Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM), pp. 97–104 (2013)
291. Niu, X., Coutinho, J.G.F., Luk, W.: A scalable design approach for stencil computation on reconfigurable clusters. In: Proceedings of the 23rd International Conference on Field programmable Logic and Applications (FPL), pp. 1–4 (2013)
292. Niu, X., Jin, Q., Luk, W., Liu, Q., Pell, O.: Exploiting run-time reconfiguration in stencil computation. In: Proceedings of the 22nd International Conference on Field programmable Logic and Applications (FPL), pp. 173–180 (2012)
293. Niu, X., Tsoi, K.H., Luk, W.: Reconfiguring distributed applications in FPGA accelerated cluster with wireless networking. In: Proceedings of the 21st International Conference on Field Programmable Logic and Applications (FPL), pp. 545–550 (2011)

294. NVIDIA: Cuda zone. http://www.nvidia.com/object/cuda_home_new.html. (Accessed March 8, 2016)
295. Nymoen, K., Chandra, A., Glette, K., Torresen, J.: Decentralized harmonic synchronization in mobile music systems. In: Proceedings of the International Conference on Awareness Science & Technology (iCAST), pp. 1–6 (2014)
296. Nymoen, K., Chandra, A., Glette, K., Torresen, J., Voldsund, A., Jensenius, A.R.: PheroMusic: Navigating a Musical Space for Active Music Experiences. In: Proceedings of the International Computer Music Conference (ICMC) joint with the Sound and Music Computing Conference, pp. 1715–1718 (2014)
297. Nymoen, K., Song, S., Hafting, Y., Torresen, J.: Funky Sole Music: Gait recognition and adaptive mapping. In: Proceedings of the International Conference on New Interfaces for Musical Expression (NIME), pp. 299–302 (2014)
298. Okuma, K., Taleghani, A., de Freitas, N., Little, J., Lowe, D.: A Boosted Particle Filter: Multitarget Detection and Tracking. In: Proceedings of 8th European Conference on Computer Vision, vol. 3021, pp. 28–39 (2004)
299. Olfati-Saber, R.: Distributed Kalman filtering for sensor networks. In: Proceedings of the Conference on Decision and Control, pp. 5492–5498 (2007). DOI 10.1109/CDC.2007.4434303
300. Olsson, R.A., Keen, A.W.: Remote procedure call. The JR Programming Language: Concurrent Programming in an Extended Java pp. 91–105 (2004)
301. Ong, Y.S., Nair, P.B., Keane, A.J.: Evolutionary optimization of computationally expensive problems via surrogate modeling. AIAA Journal **41**(4), 689–696 (2003)
302. Ontañón, S., Plaza, E.: Multiagent Inductive Learning: An Argumentation-based Approach. In: J. Fürnkranz, T. Joachims (eds.) Proceedings of the 27th International Conference on Machine Learning (ICML), pp. 839–846. Omnipress, Haifa, Israel (2010)
303. Oxford: Oxford dictionaries: Adapt. http://www.oxforddictionaries.com/definition/english/adapt. (Accessed March 8, 2016)
304. Oza, N.C.: Online bagging and boosting. In: Proceedings of the IEEE International Conference on Systems, Man and Cybernetics, pp. 2340–2345 (2005)
305. Oza, N.C., Russell, S.: Experimental comparisons of online and batch versions of bagging and boosting. In: Proceedings of the seventh ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, pp. 359–364 (2001)
306. Özuysal, M., Calonder, M., Lepetit, V., Fua, P.: Fast Keypoint Recognition Using Random Ferns. IEEE Transactions on Pattern Analysis and Machine Intelligence **32**(3), 448–461 (2010). DOI 10.1109/tpami.2009.23
307. Page, I., Luk, W.: Compiling occam into Field-Programmable Gate Arrays. In: Proceedings of the International Conference on Field programmable Logic and Applications (FPL) (1991)
308. Papakonstantinou, A., Liang, Y., Stratton, J.A., Gururaj, K., Chen, D., Hwu, W.W., Cong, J.: Multilevel Granularity Parallelism Synthesis on FPGAs. In: Proceedings of the 19th Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM), pp. 178–185. IEEE (2011)
309. Parashar, M., Hariri, S.: Autonomic computing: an overview. In: Proceedings of the International Conference on Unconventional Programming Paradigms, pp. 257–269. Springer-Verlag, Berlin (2005)
310. Parsons, S., Bahsoon, R., Lewis, P.R., Yao, X.: Towards a better understanding of self-awareness and self-expression within software systems. Tech. Rep. CSR-11-03, University of Birmingham, School of Computer Science, UK (2011)
311. Paul, C., Bass, L., Kazman, R.: Software Architecture in Practice. MA: Addison-Wesley (1998)
312. Paul, C., Kazman, R., Klein, M.: Evaluating Software Architectures: Methods and Case Studies. Addison-Wesley (2002)
313. Paulson, L.: DARPA creating self-aware computing. IEEE Computer **36**(3), 24 (2003). DOI 10.1109/MC.2003.1185213
314. Peleg, A., Wilkie, S., Weiser, U.C.: Intel MMX for Multimedia PCs. Communications of the ACM **40**(1), 24–38 (1997)

315. Perkowitz, M., Philipose, M., Fishkin, K., Patterson, D.J.: Mining models of human activities from the Web. In: Proceedings of the 13th International Conference on World Wide Web, pp. 573–582 (2004)
316. Perrone, M., Liu, L.K., Lu, L., Magerlein, K., Kim, C., Fedulova, I., Semenikhin, A.: Reducing Data Movement Costs: Scalable Seismic Imaging on Blue Gene. In: Proceedings of the 26th International Parallel & Distributed Processing Symposium (IPDPS), pp. 320–329 (2012)
317. Perrone, M.P., Cooper, L.N.: When networks disagree: Ensemble methods for hybrid neural networks. Neural Networks for Speech and Image Processing, Chapman-Hall, New York pp. 126–142 (1993)
318. Peskin, C.S.: Mathematical aspects of heart physiology. Courant Institute of Mathematical Sciences, New York University New York (1975)
319. Pflugfelder, R., Bischof, H.: People Tracking across Two Distant Self-calibrated Cameras. In: Proceedings of International Conference on Advanced Video and Signal-based Surveillance. IEEE Computer Society Press (2006)
320. Pflugfelder, R., Bischof, H.: Tracking across Non-overlapping Views Via Geometry. In: Proceedings of the International Conference on Pattern Recognition (2008)
321. Phelps, S., McBurney, P., Parsons, S.: Evolutionary mechanism design: A review. Autonomous Agents and Multi-Agent Systems **21**(2), 237–264 (2010)
322. Piciarelli, C., Esterle, L., Khan, A., Rinner, B., Foresti, G.: Dynamic Reconfiguration in Camera Networks: a short survey. IEEE Transactions on Circuits and Systems for Video Technology **PP**(99), 1–13 (2015). DOI 10.1109/TCSVT.2015.2426575. (early access)
323. Pilato, C., Loiacono, D., Tumeo, A., Ferrandi, F., Lanzi, P.L., Sciuto, D.: Speeding-up expensive evaluations in highlevel synthesis using solution modeling and fitness inheritance. In: Y. Tenne, C.K. Goh (eds.) Computational Intelligence in Expensive Optimization Problems, vol. 2, pp. 701–723. Springer (2010)
324. Polikar, R.: Ensemble based systems in decision making. IEEE Circuits and Systems Magazine **6**(3), 21–45 (2006)
325. Polikar, R., Udpa, L., Udpa, S., Honavar, V.: Learn++: An incremental learning algorithm for supervised neural networks. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews **31**(4), 497–508 (2001)
326. Puckette, M.: Pure Data (PD) (software). URL http://puredata.info. (Accessed March 8, 2016)
327. Pylvänäinen, T.: Accelerometer based gesture recognition using continuous HMMs. In: Pattern Recognition and Image Analysis, pp. 639–646. Springer (2005)
328. Quaritsch, M., Kreuzthaler, M., Rinner, B., Bischof, H., Strobl, B.: Autonomous Multicamera Tracking on Embedded Smart Cameras. EURASIP Journal on Embedded Systems **2007**(1), 35–45 (2007)
329. Rajko, S., Qian, G., Ingalls, T., James, J.: Real-time gesture recognition with minimal training requirements and on-line learning. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 1–8. IEEE (2007)
330. Ramamurthy, S., Bhatnagar, R.: Tracking recurrent concept drift in streaming data using ensemble classifiers. In: Proceedings of the Sixth International Conference on Machine Learning and Applications (ICMLA), pp. 404–409. Cincinnati, Ohio (2007)
331. Rammer, I., Szpuszta, M.: Advanced .NET Remoting. Springer (2005)
332. Ramos, C., Augusto, J.C., Shapiro, D.: Ambient intelligence - the next step for artificial intelligence. IEEE Intelligent Systems **23**(2), 15–18 (2008). DOI 10.1109/MIS.2008.19
333. Rasmussen, C., Williams, C.: Gaussian Processes for Machine Learning. MIT Press (2006)
334. Reason [computer software]. URL https://www.propellerheads.se. (Accessed March 8, 2016)
335. ReconOS: A programming model and OS for reconfigurable hardware (2013). URL http://www.reconos.de/. (Accessed March 8, 2016)
336. Reisslein, M., Rinner, B., Roy-Chowdhury, A.: Smart camera networks. IEEE Computer **47**(5), 26–28 (2014)
337. Reyes, R., de Sande, F.: Automatic code generation for gpus in llc. The Journal of Supercomputing **58**(3), 349–356 (2011)

338. Richter, U., Mnif, M., Branke, J., Müller-Schloer, C., Schmeck, H.: Towards a generic observer/controller architecture for organic computing. In: C. Hochberger, R. Liskowsky (eds.) INFORMATIK 2006 – Informatik für Menschen, *LNI*, vol. P-93, pp. 112–119. Bonner Köllen Verlag (2006)
339. Rietmann, M., Messmer, P., Nissen-Meyer, T., Peter, D., Basini, P., Komatitsch, D., Schenk, O., Tromp, J., Boschi, L., Giardini, D.: Forward and adjoint simulations of seismic wave propagation on emerging large-scale GPU architectures. In: Proceedings of the Conference on High Performance Computing Networking, Storage and Analysis (SC) (2012)
340. Rinner, B., Esterle, L., Simonjan, J., Nebehay, G., Pflugfelder, R., Fernandez, G., Lewis, P.R.: Self-Aware and Self-Expressive Camera Networks. IEEE Computer **48**(7), 33–40 (2015)
341. Rinner, B., Winkler, T., Schriebl, W., Quaritsch, M., Wolf, W.: The evolution from single to pervasive smart cameras. In: Proceedings of the Second ACM/IEEE International Conference on Distributed Smart Cameras (ICDSC), pp. 1–10 (2008). DOI 10.1109/ICDSC.2008.4635674
342. Rinner, B., Wolf, W.: Introduction to Distributed Smart Cameras. Proceedings of the IEEE **96**(10), 1565–1575 (2008). DOI 10.1109/JPROC.2008.928742
343. RNA: Recursive Network Architecture. URL http://www.isi.edu/rna. (Accessed March 8, 2015)
344. Rochat, P.: Five levels of self-awareness as they unfold in early life. Consciousness and Cognition **12**, 717–731 (2003)
345. Russell, S.J., Norvig, P.: Artificial Intelligence - A Modern Approach, 3 edn. Pearson Education (2010)
346. Saaty, T.L.: The Analytical Hierarchical Process. McGraw-Hill (1980)
347. Sakellari, G.: The cognitive packet network: A survey. The Computer Journal **53** (2010)
348. SanMiguel, J.C., Shoop, K., Cavallaro, A., Micheloni, C., Foresti, G.L.: Self-Reconfigurable Smart Camera Networks. IEEE Computer **47**(5), 67–73 (2014)
349. Santambrogio, M., Hoffmann, H., Eastep, J., Agarwal, A.: Enabling technologies for self-aware adaptive systems. In: 2010 NASA/ESA Conference on Adaptive Hardware and Systems (AHS), pp. 149–156. IEEE (2010)
350. Santner, J., Leistner, C., Saffari, A., Pock, T., Bischof, H.: PROST: Parallel robust online simple tracking. In: Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 723–730 (2010)
351. Schaumeier, J., Jeremy Pitt, J., Cabri, G.: A tripartite analytic framework for characterising awareness and self-awareness in autonomic systems research. In: Proceedings of the Sixth IEEE Conference on Self-Adaptive and Self-Organizing Systems Workshops (SASOW), pp. 157–162 (2012)
352. Schlömer, T., Poppinga, B., Henze, N., Boll, S.: Gesture recognition with a Wii controller. In: Proceedings of the 2nd International Conference on Tangible and Embedded Interaction, pp. 11–14. ACM (2008)
353. Schmeck, H.: Organic computing - a new vision for distributed embedded systems. In: Proceedings of the Eighth IEEE International Symposium on Object-Oriented Real-Time Distributed Computing (ISORC), pp. 201–203 (2005)
354. Schmickl, T., Thenius, R., Moslinger, C., Timmis, J., Tyrrell, A., Read, M., Hilder, J., Halloy, J., Campo, A., Stefanini, C., Manfredi, L., Orofino, S.: CoCoRo–The Self-Aware Underwater Swarm. In: Proceedings of the International Conference on Self-Adaptive and Self-Organizing Systems Workshops (SASOW), pp. 120–126. IEEE Computer Society, Ann Arbor, MI, USA (2011)
355. Schnier, T., Yao, X.: Using negative correlation to evolve fault-tolerant circuits. In: Proceedings of the 5th International Conference on Evolvable Systems: From Biology to Hardware (ICES'2003) – Lecture Notes in Computer Science, vol. 2606, pp. 35–46. Springer-Verlag (2003)
356. Scholz, M., Klinkenberg, R.: Boosting classifiers for drifting concepts. Intelligent Data Analysis **11**(1), 3–28 (2007)
357. Sharan, K.: Java remote method invocation. In: Beginning Java 8 APIs, Extensions and Libraries, chap. 7, pp. 525–548. Springer (2014)

358. Shaw, M.J., Sikora, R.: A distributed problem-solving approach to inductive learning. Tech. Rep. CMU-RI-TR-90-262, School of Computer Science, Carnegie Mellon University (1990)
359. Shipp, C.A., Kuncheva, L.I.: Relationships between combination methods and measures of diversity in combining classifiers. Information Fusion **3**(2), 135–148 (2002)
360. Showerman, M., Enos, J., Pant, A., Kindratenko, V., Steffen, C., Pennington, R., mei Hwu, W.: QP: A heterogeneous multi-acceleator cluster. In: Proceedings of the International Conference on High-Performance Clustered Computing (2009)
361. Shukla, S.K., Yang, Y., Bhuyan, L.N., Brisk, P.: Shared memory heterogeneous computation on PCIe-supported platforms. In: Proceedings of the 23rd International Conference on Field programmable Logic and Applications (FPL), pp. 1–4 (2013)
362. Simonjan, J., Esterle, L., Rinner, B., Nebehay, G., Dominguez, G.F.: Demonstrating autonomous handover in heterogeneous multi-camera systems. In: Proceedings of the International Conference on Distributed Smart Cameras, pp. 43:1–43:3 (2014). DOI 10.1145/2659021.2669474
363. Sironi, F., Bartolini, D.B., Campanoni, S., Cancare, F., Hoffmann, H., Sciuto, D., Santambrogio, M.D.: Metronome: Operating System Level Performance Management via Self-adaptive Computing. In: Proceedings of the Design Automation Conference (DAC). ACM (2012)
364. Sironi, F., Cuoccio, A., Hoffmann, H., Maggio, M., Santambrogio, M.: Evolvable Systems on Reconfigurable Architecture via Self-aware Adaptive Applications. In: Proceedings of the NASA/ESA Conference on Adaptive Hardware and Systems (AHS) (2011). DOI 10.1109/AHS.2011.5963933
365. Sironi, F., Triverio, M., Hoffmann, H., Maggio, M., Santambrogio, M.: Self-aware Adaptation in FPGA-based Systems. In: Proceedings of the International Conference on Field Programmable Logic and Applications. IEEE (2010)
366. Smallwood, J., McSpadden, M., Schooler, J.: The lights are on but no one's home: meta-awareness and the decoupling of attention when the mind wanders. Psychonomic Bulletin and Review **14**(3), 527–533 (2007)
367. Song, S., Chandra, A., Torresen, J.: An ant learning algorithm for gesture recognition with one-instance training. In: Proceedings of the International Congress on Evolutionary Computation (CEC), pp. 2956–2963. IEEE (2013)
368. SRC Computers, L.: SRC-7 MAPstation. Tech. rep., SRC Computers (2009)
369. Srinivas, N., Deb, K.: Multiobjective optimization using nondominated sorting in genetic algorithms. Evolutionary Computation **2**(3), 221–248 (1994)
370. Stanley, K.O.: Learning concept drift with a committee of decision trees. Tech. Rep. UT-AI-TR-03-302, Department of Computer Sciences, University of Texas at Austin (2003)
371. Sterritt, R., Parashar, M., Tianfield, H., Unland, R.: A concise introduction to autonomic computing. Advanced Engineering Informatics **19**(3), 181–187 (2005)
372. Steuer, R.E., Choo, E.U.: An interactive weighted Tchebycheff procedure for multiple objective programming. Mathematical Programming **26**(3), 326–344 (1983)
373. Stone, P.: Layered Learning in Multiagent Systems: A Winning Approach to Robotic Soccer. MIT Press (2000)
374. Strassen, V.: Gaussian elimination is not optimal. Numerische Mathematik pp. 13:354–356 (1969)
375. Street, W., Kim, Y.: A streaming ensemble algorithm (SEA) for large-scale classification. In: Proceedings of the Seventh ACM International Conference on Knowledge Discovery and Data Mining (KDD), pp. 377–382. New York (2001)
376. Strenski, D.: The Cray XD1 computer and its reconfigurable architecture. Tech. rep., Cray Inc. (2005)
377. Strey, A., Bange, M.: Performance Analysis of Intel's MMX and SSE: A Case Study. In: Proceedings of 7th International Euro-Par Conference on Parallel Processing (Euro-Par), pp. 142–147. Manchester, UK (2001)
378. Susanto, K.W., Todman, T., Coutinho, J.G.F., Luk, W.: Design Validation by Symbolic Simulation and Equivalence Checking: A Case Study in Memory Optimization for Image Manipulation, *LNCS*, vol. 5404, pp. 509–520. Springer (2009)

379. Sutter, H.: The free lunch is over: A fundamental turn toward concurrency in software. Dr. Dobb's Journal (2005)
380. Sutton, R.S., Barto, A.G.: Reinforcement Learning: An Introduction. MIT Press (1998)
381. Taj, M., Cavallaro, A.: Distributed and decentralized multi-camera tracking. IEEE Signal Processing Magazine **28**(3), 46–58 (2011)
382. Tawney, G.A.: Feeling and self-awareness. Psyc. Rev. **9**(6), 570 – 596 (1902)
383. Tesauro, G.: Reinforcement learning in autonomic computing: A manifesto and case studies. IEEE Internet Computing **11**(1), 22–30 (2007)
384. Thomas, D., Luk, W.: Non-uniform random number generation through piecewise linear approximations. In: Proceedings of the International Conference on Field Programmable Logic and Applications (FPL), pp. 1–6 (2006)
385. Thomas, D.B., Luk, W.: Credit Risk Modelling using Hardware Accelerated Monte-Carlo Simulation. In: Proceedings of the 16th IEEE International Symposium on Field-Programmable Custom Computing Machines (FCCM), pp. 229–238 (2008)
386. Todman, T., Boehm, P., Luk, W.: Verification of streaming hardware and software codesigns. In: Proceedings of the International Conference on Field Programmable Technology (ICFPT), pp. 147–150. IEEE (2012)
387. Todman, T., Stilkerich, S.C., Luk, W.: Using Statistical Assertions to Guide Self-Adaptive Systems. International Journal of Reconfigurable Computing **2014**, 1–8 (2014). DOI 10.1155/2014/724585
388. Tong, X., Ngai, E.: A ubiquitous publish/subscribe platform for wireless sensor networks with mobile mules. In: Proceedings of the IEEE Eighth International Conference on Distributed Computing in Sensor Systems (DCOSS), pp. 99–108 (2012)
389. Torresen, J., Hafting, Y., Nymoen, K.: A new Wi-Fi based platform for wireless sensor data collection. In: Proceedings of the International Conference on New Interfaces for Musical Expression, pp. 337–340 (2013)
390. Torresen, J., Plessl, C., Yao, X.: Special Issue on "Self-Aware and Self-Expressive Systems". IEEE Computer **48**(7), 45–51 (2015)
391. Touch, J., Pingali, V.: The RNA Metaprotocol. In: Proceedings of the International Conference on Computer Communications and Networks, pp. 1–6 (2008). DOI 10.1109/ICCCN.2008.ECP.46
392. Trucco, E., Plakas, K.: Video Tracking: A Concise Survey. Journal of Oceanic Engineering **31**(2), 520–529 (2006)
393. Tse, A.H.T., Chow, G.C.T., Jin, Q., Thomas, D.B., Luk, W.: Optimising performance of quadrature methods with reduced precision. In: Proceedings of the International Conference on Reconfigurable Computing: Architectures, Tools and Applications (ARC), *Lecture Notes in Computer Science*, vol. 7199, pp. 251–263. Springer (2012). DOI 10.1007/978-3-642-28365-9_21
394. Tse, A.H.T., Thomas, D.B., Tsoi, K.H., Luk, W.: Dynamic scheduling Monte-Carlo framework for multi-accelerator heterogeneous clusters. In: Proceedings of the International Conference on Field-Programmable Technology (FTP), pp. 233–240 (2010)
395. Tsoi, K.H., Luk, W.: Axel: A Heterogeneous Cluster with FPGAs and GPUs. In: Proceedings of the 18th annual ACM/SIGDA International Symposium on Field Programmable Gate Arrays, pp. 115–124 (2010)
396. Tsymbal, A., Pechenizkiy, M., Cunningham, P., Puuronen, S.: Dynamic integration of classifiers for handling concept drift. Information Fusion **9**(1), 56–68 (2008)
397. Vassev, E., Hinchey, M.: Knowledge representation and awareness in autonomic service-component ensembles – state of the art. In: 14th IEEE International Symposium on Object/Component/Service-oriented Real-time Distributed Computing, pp. 110–119 (2011)
398. Vasudevan, S.: What is assertion-based verification? SIGDA E-News **42**(12) (2012)
399. Vermorel, J., Mohri, M.: Multi-Armed Bandit Algorithms and Empirical Evaluation. In: Proceedings of the European Conference on Machine Learning, pp. 437–448. Springer (2005)
400. Vickrey, W.: Counterspeculation, auctions, and competitive sealed tenders. The Journal of Finance **16**(1), 8–37 (1961)

401. Vinoski, S.: CORBA: Integrating diverse applications within distributed heterogeneous environments. IEEE Communications Magazine **35**(2), 46–55 (1997)
402. Volker, L., Martin, D., El Khayaut, I., Werle, C., Zitterbart, M.: A Node Architecture for 1000 Future Networks. In: Proceedings of the IEEE International Conference on Communications (ICC), pp. 1–5 (2009). DOI 10.1109/ICCW.2009.5207996
403. Volker, L., Martin, D., Werle, C., Zitterbart, M., El-Khayat, I.: Selecting Concurrent Network Architectures at Runtime. In: Proceedings of the IEEE International Conference on Communications (ICC), pp. 1–5 (2009). DOI 10.1109/ICC.2009.5199445
404. Wang, J., Brady, D., Baclawski, K., Kokar, M., Lechowicz, L.: The use of ontologies for the self-awareness of the communication nodes. In: Proceedings of the Software Defined Radio Technical Conference (SDR), vol. 3 (2003)
405. Wang, S., Minku, L.L., Yao, X.: A learning framework for online class imbalance learning. In: Proceedings of the IEEE Symposium on Computational Intelligence and Ensemble Learning (CIEL), pp. 36–45 (2013)
406. Wang, S., Minku, L.L., Yao, X.: Online class imbalance learning and its applications in fault detection. International Journal of Computational Intelligence and Applications **12**(1340001), (1–19) (2013)
407. Wang, S., Minku, L.L., Yao, X.: A multi-objective ensemble method for online class imbalance learning. In: Proceedings of the International Joint Conference on Neural Networks (IJCNN), pp. 3311–3318. IEEE (2014). DOI 10.1109/IJCNN.2014.6889545
408. Wang, S., Minku, L.L., Yao, X.: Resampling-based ensemble methods for online class imbalance learning. In: IEEE Transactions on Knowledge and Data Engineering, vol. 27, pp. 1356–1368. IEEE (2015). DOI 10.1109/TKDE.2014.2345380
409. Wang, Z., Tang, K., Yao, X.: A memetic algorithm for multi-level redundancy allocation. IEEE Transactions on Reliability **59**(4), 754–765 (2010)
410. Watson, R.: The Delta-t Transport Protocol: Features and Experience. In: Proceedings 14th Conference on Local Computer Networks, pp. 399–407 (1989). DOI 10.1109/LCN.1989.65288
411. Werner-Allen, G., Tewari, G., Patel, A., Welsh, M., Nagpal, R.: Firefly-inspired sensor network synchronicity with realistic radio effects. In: Proceedings of the 3rd International Conference on Embedded Networked Sensor Systems, pp. 142–153 (2005)
412. Weyns, D., Schmerl, B., Grassi, V., Malek, S., Mirandola, R., Prehofer, C., Wuttke, J., Andersson, J., Giese, H., Gäschka, K.M.: On patterns for decentralized control in self-adaptive systems. In: R. Lemos, H. Giese, H. Müller, M. Shaw (eds.) Software Engineering for Self-Adaptive Systems II, *Lecture Notes in Computer Science*, vol. 7475, pp. 76–107. Springer Berlin Heidelberg (2013)
413. Wikipedia: Adaptation (computer science). http://en.wikipedia.org/wiki/Adaptation. (Accessed March 8, 2016)
414. Winfield, A.: Robots with internal models: a route to self-aware and hence safer robots. In: J. Pitt (ed.) The Computer After Me. Imperial College Press / World Scientific Book (2014)
415. Wolf, W., Ozer, B., Lv, T.: Smart Cameras as Embedded Systems. IEEE Computer **35**(9), 48–53 (2002)
416. Wright, M.: Open Sound Control: an enabling technology for musical networking. Organised Sound **10**(3), 193–200 (2005)
417. Xiao, L., Zhu, Y., Ni, L., Xu, Z.: GridIS: An Incentive-Based Grid Scheduling. In: Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium, p. 65b (2005). DOI 10.1109/IPDPS.2005.237
418. Xilinx: SDAccel Development Environment. http://www.xilinx.com/products/design-tools/sdx/sdaccel.html. (Accessed March 8, 2016)
419. Ye, J., Dobson, S., McKeever, S.: Situation identification techniques in pervasive computing: A review. Pervasive and Mobile Computing **8**(1) (2012)
420. Yiannacouras, P., Steffan, J.G., Rose, J.: VESPA: portable, scalable, and flexible FPGA-based vector processors. In: Proceedings of the International Conference on Compilers, Architecture, and Synthesis for Embedded Systems, pp. 61–70 (2008)

421. Yilmaz, A., Javed, O., Shah, M.: Object Tracking: A Survey. ACM Computing Surveys **38**(4), 1–45 (2006)
422. Yin, F., D., M., Velastin, S.: Performance evaluation of object tracking algorithms. In: Proceedings of the International Workshop on Performance Evaluation of Tracking and Surveillance (2007)
423. Yin, L., Dong, M., Duan, Y., Deng, W., Zhao, K., Guo, J.: A high-performance training-free approach for hand gesture recognition with accelerometer. Multimedia Tools and Applications pp. 1–22 (2013)
424. Yu, X., Tang, K., Chen, T., Yao, X.: Empirical analysis of evolutionary algorithms with immigrants schemes for dynamic optimization. Memetic Computing **1**(1), 3–24 (2009)
425. Zadeh, L.: Optimality and non-scalar-valued performance criteria. IEEE Transactions on Automatic Control **8**(1), 59–60 (1963)
426. Zagal, J.C., Lipson, H.: Towards self-reflecting machines: Two-minds in one robot. In: Advances in Artificial Life. Darwin Meets von Neumann, *Lecture Notes in Computer Science*, vol. 5777, pp. 156–164. Springer (2011)
427. Zambonelli, F., Bicocchi, N., Cabri, G., Leonardi, L., Puviani, M.: On self-adaptation, self-expression, and self-awareness in autonomic service component ensembles. In: Proceedings of the Fifth IEEE Conference on Self-Adaptive and Self-Organizing Systems Workshops (SASOW), pp. 108 –113 (2011)
428. Zarezadeh, A.A., Bobda, C.: Hardware Middleware for Person Tracking on Embedded Distributed Smart Cameras. Hindawi International Journal of Reconfigurable Computing (2012)
429. Zeppenfeld, J., Bouajila, A., Stechele, W., Bernauer, A., Bringmann, O., Rosenstiel, W., Herkersdorf, A.: Applying ASoC to Multi-core Applications for Workload Management. In: C. Müller-Schloer, H. Schmeck, T. Ungerer (eds.) Organic Computing – A Paradigm Shift for Complex Systems, *Autonomic Systems*, vol. 1, pp. 461–472. Springer Basel (2011)
430. Zhou, A., Qu, B.Y., Li, H., Zhao, S.Z., Suganthan, P.N., Zhang, Q.: Multiobjective evolutionary algorithms: A survey of the state of the art. Swarm and Evolutionary Computation **1**(1), 32–49 (2011)
431. Ziliani, F., Velastin, S., Porikli, F., Marcenaro, L., Kelliher, T., Cavallaro, A., Bruneaut, P.: Performance evaluation of event detection solutions: the CREDS experience. In: Proceedings of the International Conference on Advanced Video and Signal Based Surveillance, pp. 201–206 (2005)
432. Zitzler, E., Deb, K., Thiele, L.: Comparison of Multiobjective Evolutionary Algorithm: Empirical Results. Evolutionary Computation **8**(2), 173–195 (2000)
433. Zitzler, E., Künzli, S.: Indicator-Based Selection in Multiobjective Search. In: Proceedings of the International Conference on Parallel Problem Solving from Nature (PPSN), vol. 3242, pp. 832–842 (2004)
434. Zitzler, E., Laumanns, M., Thiele, L.: SPEA2: Improving the Strength Pareto Evolutionary Algorithm. Tech. Rep. 103, Computer Engineering and Networks Laboratory (TIK), Swiss Federal Institute of Technology (ETH), Zurich (2001)
435. Zitzler, E., Thiele, L.: Multiobjective evolutionary algorithms: a comparative case study and the strength Pareto approach. IEEE Transactions on Evolutionary Computation **3**(4), 257–271 (1999)
436. Zitzler, E., Thiele, L., Laumanns, M., Fonseca, C.M., da Fonseca, V.G.: Performance assessment of multiobjective optimizers: An analysis and review. IEEE Transactions on Evolutionary Computation **7**(2), 117–132 (2003)