Annotated Bibliography

[1] J.S. Aitken, F. Schmalhofer, and N. Shadbolt. A knowledge level characterization of multi-agent systems. In *Proceedings of ECAI Workshop on Agent Theories, Architectures, and Languages*, 1994.

KEY: Aitken94
ANNOTATION: This paper presents a knowledge–based analysis of a number of multi–agent systems, based on the knowledge level hypothesis of Newell and Clancey. The central feature of knowledge level characterization is their focus on rational activity based on a fruitless notion of knowledge. This provides the theoretical background which we use to characterize a number of existing systems, and specifies an approach which abstracts away from implementational details to show essential problem solving actions of the distributed system. We used some of these concepts to formalize multi–agent manufacturing systems

[2] D. Ben-Arieh and M. Chopra. A game theoretic approach to real-time distributed shop floor control. In *Proceedings of Sixth Industrial Engineering Research Conference*, pages 304–309, May 1997.

KEY: Ben-Arieh97
ANNOTATION: This paper presents a game theoretic approach for the shop floor control. The operations to be performed on a parts act as players with the alternate machines used as their strategies. The operation selects the machines, which leads it to the maximum payoff. The payoff to an operation using a particular strategy considers the present system status and the future operations on the job, thus avoiding myopic decisions.

[3] L. Bongaerts, P. Valckenaers, H.V. Brussel, and J. Wyns. Schedule execution for a holonic shop floor control system. In *Proceedings of Advanced Summer Institute '95 of the Network of Excellence in Intelligent Control and Integrated Manufacturing Systems*, pages 115–124, Lisboa, June 1995.

KEY: Bongaerts95
ANNOTATION: A holonic manufacturing system is a highly

decentralized system consisting of cooperative, intelligent, autonomous modules, called holons, that together yield an agile and self–organizing manufacturing system and support global optimization. Using partial derivatives of the objective functions to the disturbances, the shop floor control holon can automatically react to disturbances while considering global performance.

[4] P. Burke and P. Prosser. A distributed asynchronous system for predictive and reactive scheduling. *Artificial Intelligence in Engineering*, 6(3):106–123, July 1991.

KEY: Burke91
ANNOTATION: In the distributed asynchronous scheduler, the scheduling problem is decomposed both functionally and spatially across a hierarchy of communicating agents where each agent exhibits the properties of opportunism, reaction and belief maintenance. Each agent corresponds to a distinct software process, all of which may run concurrently. To be able to work towards a global solution each agent may react to change induced upon it by other agents and is able to negotiate with agents. The external world is treated as an agent with one exceptional property, negotiation is disallowed. The system is disciplined such that the problem solving effort can be dynamically focused and decision making synchronized.

[5] H.-D. Burkhard. Agent-oriented programming for open systems. In *ECAI Workshop on Agent Theories, Architectures, and Languages*, pages 291–306, 1994.

KEY: Burkhard94
ANNOTATION: The aim of this paper is to collect arguments under the special viewpoint of agent oriented programming for open systems. The author argues that there is no unique notion of an agent and different principles and different languages/tools are necessary for different agent roles.

[6] C. Castelfranchi. Guarantees for autonomy in cognitive agent architecture. In *ECAI Workshop on Agent Theories, Architectures, and Languages*, pages 56–70, 1994.

KEY: Castelfranchi94
ANNOTATION: This paper analyzes which features of an agent architecture determine its autonomy. Some of these ideas could be used in a formal requirements definition for negotiation.

[7] P. Cohen, A. Cheyer, M. Wang, and S.C. Baeg. OAAA: An open agent architecture. In *Proceedings of AAAI Spring Symposium*, 1994.

KEY: Cohen94
ANNOTATION: This paper presents an open agent architecture and accompanying user interface for networked desktop and hand-held machines. This system supports distributed execution of a user's requests interoperability of multiple application subsystems, addition of new agents, and incorporation of existing applications. It is also transparent; users do not know where their requests are being processed, nor how. In order to facilitate the user's delegating tasks to agents, the architecture is served by a multi-modal interface, including pen, voice, and direct manipulation.

[8] R. Davis and R.G. Smith. Negotiation as a metaphor for distributed problem solving. *Artificial Intelligence*, 20:63–109, 1983.

KEY: Davis83
ANNOTATION: This paper presents a framework called contract net that specifies communication and control in a distributed problem solver. Task distribution us viewed as an interactive process, a discussion carried on between a node with a task to be executed and a group of nodes that may be able to execute the task. This work has been the basis for most of the research done in distributed control of manufacturing.

[9] A.V. Deshmukh, S. Benjaafar, J.J. Talavage, and M.M. Barash. Comparison of centralized and distributed control policies for manufacturing systems. In *Proceedings of 2nd Industrial Engineering Research Conference Proceedings*, pages 744–748, 1993.

KEY: Deshmukh93
ANNOTATION: This paper presents a comparison of the ef-

fect of varying degrees of opportunism and system information in the dynamic distributed control policies and compares the performance of these policies with static centralized or planning based policies. The primary goal of this paper was to use queuing analogies to understand the shop floor control policies. This analysis provides a framework for comparing system behavior under different operating conditions for shop floor control policies.

[10] N.A. Duffie. Synthesis of heterarchical manufacturing systems. *Computers in Industry*, 14:167–174, 1990.

KEY: Duffie90
ANNOTATION: This paper is devoted to a discussion of objectives and philosophies for heterarchical systems. An automated mold production system with a heterarchical architecture is discussed as an example. This paper primarily promotes the idea of decentralization of control and shows how fault tolerance can be included in this architecture.

[11] N.A. Duffie and R.S. Piper. Non-hierarchical control of a flexible manufacturing cell. *Robotics & computer-integrated manufacturing*, 3(2):175–179, 1987.

KEY: Duffie87
ANNOTATION: This paper presents a non-hierarchical control system designed at the University of Wisconsin-Madison.

[12] N.A. Duffie and V.V. Prabhu. Heterarchical control of highly distributed manufacturing systems. *International Journal of Computer Integrated Manufacturing*, 9(4):270–281, 1996.

KEY: Duffie96
ANNOTATION: In this paper, design principles for heterarchical systems are reviewed that have evolved to promote reduced complexity, increased extensibility, self configurability, and adaptation in real time. A local control method based on closed–loop feedback rather than heuristics has been developed for decentralized manufacturing systems. The arrival

time controllers of parts try to minimize earliness as well as tardiness.

[13] C. Grossner, A.D. Preece, T. Radhakrishnan, and M. Newborn. Sharing data in multi-agent systems. Available at `http://www.cs.concordia.ca/~staffcs/cliff/dai/dai-list.html`, September 1995.

KEY: Grossner95
ANNOTATION: This paper presents a model and tools for aiding the designer of MAS in analyzing the data distribution, when agents are implemented as rule–based systems. Using path model the MAS designer is able to analyze the effects of a particular data distribution and determine how the data distribution in an MAS can be modified in order to improve the performance of the agents.

[14] I.-K. Jeong and J.-J. Lee. Evolving multi-agents using a self-organizing genetic algorithm. *Applied Mathematics and Computation*, 88(2):293–303, Dec 1997.

KEY: Jeong97
ANNOTATION: This paper introduces the use of a genetic algorithm to discover rules that govern emergent cooperative behavior. A self-organizing genetic algorithm was applied to automating the discovery of rules for multi-agents playing soccer. Although the authors did not use comprehensive knowledge about the system, the genetic algorithm successfully discovered rules that govern emergent cooperative behavior. Simulation results indicate that an evolutionary approach to find the appropriate rules for emergent cooperative behavior seems to be promising.

[15] N. Komodo, K. Kera, and T. Kubo. An autonomous, decentralized control system for factory automation. *Computer*, pages 73–83, December 1984.

KEY: Komodo84
ANNOTATION: Hitachi's total factory automation systems are based on distributed workstations adaptable enough for use in a variety of industries. Key components are the flexible

manufacturing cell controller and a process local area network. This paper presents a detailed design of a FMS developed at Hitachi.

[16] TH. Laengle and T.C. Lueth. Decentralized control of distributed intelligent robots and subsystems. In *Proceedings of the IFAC Symposium on Artificial Intelligence in Real Time Control*, Valencia, Spain, 1994.

KEY: Laengle94
ANNOTATION: This paper presents a distributed control architecture of the KAMRO which is developed at IPR. The described concept uses local intelligence, decentralized communication, teams and special agents.

[17] S.E. Lander and V.R. Lesser. Understanding the role of negotiation in distributed search among heterogeneous agents. In *Proceedings of the International Joint Conference on Artificial Intelligence*, 1993.

KEY: Lander93
ANNOTATION: This paper explores the role of negotiation for conflict resolution in distributed search among heterogeneous and reusable agents. It presents an algorithm that explicitly recognizes and exploits conflict to direct search activity across a set of agents. Results from experiments conducted with negotiated search show that the algorithm can produce high quality solutions and the algorithm is flexible enough to work in a reusable agents systems where the search operators are randomly distributed across the agent set.

[18] M.M. Lewis, W.and Barash and J.J. Solberg. Computer integrated manufacturing system control: A data flow approach. *Journal of Manufacturing Systems*, 6(3):177–191, 1982.

KEY: Lewis82
ANNOTATION: A control system for computer integrated manufacturing systems is analyzed and described which, in simulation, produces machine utilizations in excess of 90% and accepts priority. This is one of the earliest works in the area of distributed control of manufacturing systems, which uses ethernet as a communication channel between machines.

[19] G. Lin and J.J. Solberg. Integrated shop floor control using autonomous agents. *IIE Transactions*, 24(3):57–71, July 1992.

KEY: Lin92
ANNOTATION: Based on a market-like model and a combination of objectives and price mechanism, the framework allows heterogeneous job objectives, admits job priorities, recognizes multiple resource types, and allows multiple step negotiation between parts and resources. This framework accommodates frequent changes in the environment such as machine failures, tool shortages, and process requirement variations. An object–oriented simulations is built to demonstrate th flexibility and effectiveness of the proposed framework. The results show that the proposed framework provides a foundation for highly adaptive, real time shop floor control. In our research, currency was used as a metric for guiding communication between parts and machines. Also, the simulation was conducted in Swarm, an object–oriented simulation framework.

[20] J.G. Maley. Managing the flow of intelligent parts. *Robotics & Computer-Integrated Manufacturing*, 4(3/4):525–530, 1988.

KEY: Maley88b
ANNOTATION: The CADENCE system, introduced in this research, manages the physical parts' operations and information flow within manufacturing. Integration of both the physical flow dependencies and the information flow is provided by a negotiation procedure. This paper contributed to the later work in distributed control of manufacturing systems.

[21] L. Overgaard, H.G. Petersen, and J.W. Perram. Reactive motion planning: A multiagent approach. *Applied Artificial Intelligence*, 10(1):35–48, 1996.

KEY: Overgaard96
ANNOTATION: This presents an efficient approach to reactive robot motion planning and collision avoidance. Links and joints of the robot are autonomous agents which is a new approach. The emergent behavior of the multi–agent system gives an impression of surprisingly intelligent overall control.

[22] L. Parker. Designing control laws for cooperative agent teams. In *Proceedings of IEEE Conference on Robotics and Automation*, pages 582–587, 1993.

Key: Parker93
Annotation: This paper presents some general guidelines and principles for determining the appropriate level of global versus local control to achieve coherent cooperation without excessive communication requirements. This paper addresses this issue by presenting some general guidelines and principles for determining the appropriate level of global versus local control. The author concludes that the use of local control information to ground global knowledge in the current situation is perhaps the best way to achieve the proper balance between local and global control.

[23] L.E. Parker. Adaptive action selection for cooperative agent teams. In *Proceedings of Second International Conference on Simulation of Adapting Behavior*, pages 442–450, 1992.

Key: Parker92
Annotation: This paper discusses two types of animal societies - differentiating and integrative - and their parallels to cooperative mobile robot work. This paper then presents an architecture for adaptive action selection in teams of cooperative agents of the second, integrative, type of society. In this architecture, task allocation is achieved through the selfish interests of individual agents, modified by the current and previous actions of other team members. The results of simulation experiments are presented which show this architecture to be successful in allowing agents to adapt their actions both to a dynamic environment and to the actions of other agents.

[24] L.E. Parker. Alliance: An architecture for fault tolerant, cooperative control of heterogeneous mobile robots. In *Proceedings of International Conference on Intelligent Robots and Systems*, pages 776–783, 1994.

Key: Parker94
Annotation: ALLIANCE is a software architecture that fa-

cilitates the fault tolerant cooperative control of teams of heterogeneous mobile robots performing missions composed of loosely coupled, largely independent subtasks. This architecture utilizes no form of negotiation or two-way conversations; instead it uses a simple form of broadcast communication that allows robots to be aware of actions of their teammates. The same kind of design was used in our research in which machines broadcasted messages to the selected parts, which was used as fault tolerance.

[25] L.E. Parker. The effect of action recognition and robot awareness in cooperative robotic teams. In *Proceedings of International Conference on Intelligent Robots and Systems*, pages 212–219, 1995.

Key: Parker95
Annotation: The research described in this paper investigates this issue of robot awareness of team member actions and its effect on cooperative team performance by examining the results of a series of experiments on teams of mobile robots performing a puck moving mission. The loss of awareness leads robots to select their actions based purely on feedback from the world through the remaining sensors. This information was used to design fault tolerance in the MA manufacturing system in our research. Lack of awareness caused redundant execution of certain tasks by robots.

[26] H.V.D. Parunak, A.D. Baker, and S.J. Clark. The aaria agent architecture: An example of requirements-driven agent-based system design. In *Proceedings of Agents 1997*, pages 482–48, 1997.

Key: Parunak97
Annotation: Needs driven approach is applied in AARIA, an industrial strength agent based factory scheduling and simulation system being developed for an Army manufacturing facility. In AARIA, the authors use linguistic case theory over a set of declarative sentences describing the domain to identify candidate agents, then refine this population using the requirements.

[27] H.V.D. Parunak, A. Ward, and J. Sauter. A systematic market approach to distributed constraint problems. 1998. Submitted to ICMAS'98.

KEY: Parunak98
ANNOTATION: Market based constraints applies market based control to distributed constraint problems. Constraint agents interact with one another via the variable agents in which they have a common interest, using expressions of their preferences over sets of assignments. Each variable integrates this information from the constraints interested in it and provides feedback that enables the constraints to shrink their sets of assignments until they converge on a solution.

[28] T. Sandholm. An implementation of the contract net protocol based on marginal cost calculations. *AAAI*, pages 256–262, 1993.

KEY: Sandholm93
ANNOTATION: This paper presents a formalization of the bidding and awarding decision process that was left undefined in the original contract net task allocation protocol. This formalization is based on marginal cost calculations based on local agent criteria. The contract net protocol is extended to allow for the possibility of a large number of announcements and bid message and to effectively handle situations, in which new bidding and awarding is being done during the period when the results of the previous bids are unknown.

[29] T. Sandholm and V. Lesser. *Reading in Agents*, chapter Issues in Automated Negotiation and Electronic Commerce: Extending the Contract Net Framework, pages 66–73. Morgan Kaufmann Publishers, 1998.

KEY: Sandholm98
ANNOTATION: This paper presents a number of previously unaddressed issues that arise in automated negotiation among self-interested agents whose rationality is bounded by computational complexity. These issues are presented in the context of iterative task allocation negotiations. Techniques for linking negotiation items and multi–agent contracts are presented as methods for escaping the local optima in the task allocation process.

[30] T. Sandholm and F. Ygge. On the gains and losses of speculation in equilibrium markets. In *Proceedings of 15th International Joint Conference on Artificial Intelligence*, Nagoya, Japan, 1997.

KEY: Sandholm97
ANNOTATION: This paper presents a method for computing the maximal advantage of speculative behavior in equilibrium markets. It is computed from the other agents' supply/demand functions. This method enables one to analyze how much an agent could gain or lose by speculating in a particular system, and is also useful in evaluating different strategies since it allows one to determine how close to the optimal strategy they are. The authors also discussed the protocol dependent game theoretic issues related to multiple agents counterspeculating.

[31] T.W. Sandholm and V.R. Lesser. Coalition formation among bounded rational agents. In *Proceedings of 14th International Joint Conference on Artificial Intelligence (IJCAI-95)*, pages 662–669, Montreal, Canada, 1995.

KEY: Sandholm95
ANNOTATION: This paper analyzes coalition formation among self–interested agents that need to solve combinatorial optimization problems to operate efficiently in the world. Solution quality is decision theoretically traded off against computation cost, where the model of bounded rationality is based on costly computation resources.

[32] S. Sen and E. H. Durfee. The role of commitment in cooperative negotiation. *International Journal on Intelligent & Cooperative Information Systems*, 3(1):7–81, 1994.

KEY: Sen94
ANNOTATION: This paper investigates the use of commitment by agents to proposed actions as a mechanism that allow agents to work concurrently on interdependent problems. The authors have investigated the effect of two simple commitment strategies in the domain of the distributed scheduling in the

which the agents manage local resource calendars and must cooperate to bring together all the resources required to process any assigned task. The results suggest that commitment should be used sparingly, and the authors have outlined an adaptive commitment strategy that makes the most effective commitment decision based on key environmental factors.

[33] M.J. Shaw. A distributed scheduling method for computer integrated manufacturing: the use of local area networks in cellular systems. *International Journal of Production Research*, 25(9):1285–1303, 1987.

KEY: Shaw87
ANNOTATION: This paper describes a distributed scheduling approach that takes into account characteristics of the communication network in the computer-integrated manufacturing environment. This approach is based on a network–wide bidding scheme wherein the scheduling decision is based by collecting the price of each manufacturing cell for taking the job.

[34] J.M. Vidal and E.H. Durfee. Building agent models in economic societies of agents. In *AAAI-96 Workshop on Agent Modeling*, 1996.

KEY: Vidal96
ANNOTATION: This paper presents an economic society of agents in which buyers and sellers compete with each other, and try to increase their total values and total profits respectively. The authors present a method for the construction of these agents and for the incremental incorporation of modeling capabilities, following the intuitions behind the Recursive Modeling Method. Early test results show that deeper models are more effective in heterogeneous societies than in homogeneous ones, and that the price volatility is a good predictor of the relative benefits of deeper models.

[35] M. Wooldridge and N.R. Jennings. Agent theories, architectures, and languages: A survey. In *ECAI Workshop on Agent Theories, Architectures, and Languages*, pages 1–39, 1994.

KEY: Wooldridge94
ANNOTATION: This paper presents a survey of what authors perceive as the most important theoretical and practical issues associated with the design and construction of intelligent agents. This article also provides a short review existing and potential applications of agent technology, and closes with a glossary of key terms, an annotated list of systems, and a detailed bibliography.