Ecological Robotics: A Schema-theoretic Approach

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The goals of this joint U.S.-Mexico research project are threefold: (1) to provide an understanding and means by which robotic systems are not competing with other agents that are more effective at their designated task; (2) to permit them to be successful competitors within the ecological system and capable of displacing less efficient agents; and (3) that they are ecologically sensitive so that agent environment dynamics are well-modeled and as predictable as possible whenever new robotic technology is introduced. This research effort is tied together by a collection of software tools including: NSL, a neural simulation language; ASL, an abstract schema language; and *MissionLab*, a schema-based mission-oriented simulation and robot implementation environment.

Objectives: An in-depth understanding and dynamic modeling of the relationship a robot has with its environment (the overall ecology) to ensure that fielded robotic systems are:

- Not competing with other agents that can do the task more effectively and hence prove themselves useless.
- Successful competitors within the ecological system and can potentially displace less efficient agents.
- Ecologically sensitive so that agent-environmental system dynamics are well-modeled and as predictable as possible whenever new robotic technology is introduced.

Approach: Three major research questions are being answered by developing behavioral schema models [1] executed on simulation and robotic systems:

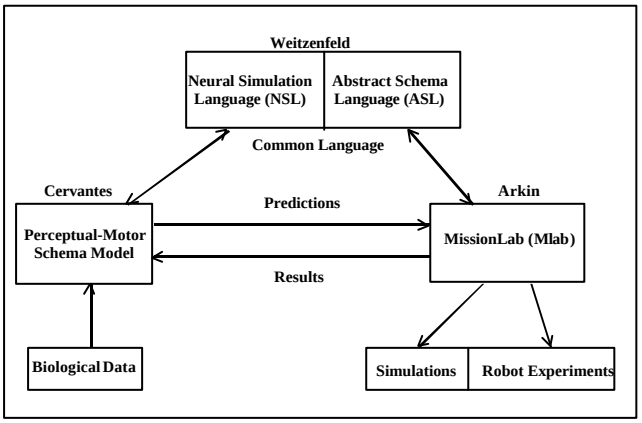

Figure 1

How can agent/environmental processes be modeled using a formal schema-based approach?

How can research in multi-agent robotic systems be extended to include not merely cooperative agents, but other complex interactions, such as competition?

How can predictive models generated from biological systems be used to drive robotic experiments, and conversely how can results from robotic experiments provide drive additional neuroscientific/ethological data gathering?

The collaborative research methodology is depicted in Figure 1. Biological data from behavioral studies, praying mantis "Chantitlaxia" [2] and frog prey acquisition and predator avoidance [3], are used to generate perceptual and motor schema models in ASL [4], implement them by neural

network models in NSL [5], and then import them into the *MissionLab* robotic system [6], for simulation or robotic experimentation.

Accomplishments-to-date: Work up to date has been in terms of (1) the extension and integration of software tools, and (2) development of new models based on biological behavioral data. We have integrated NSL with ASL, developed a heterogeneous distributed implementation of ASL [7], and developed an architecture integrating ASL/NSL to Missionlab [8]. We have developed preliminary schema models, including modulation by learning processes [9], simulated and experimented in a fielded robotic system [10][11].

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References:

[1] Arbib, M.A., "Schema Theory", in the Encyclopedia of Artificial Intelligence, 2nd Edition, Editor Stuart Shapiro, 2:1427-1443, Wiley, 1992.

[2] Cervantes-Perez, F., Franco, A., Velazquez, S., Lara, N., 1993, "A Schema Theoretic Approach to Study the 'Chantitlaxia' Behavior in the Praying Mantis", Proceeding of the First Workshop on Neural Architectures and Distributed AI: From Schema Assemblages to Neural Networks, USC, October 19-20, 1993.

[3] Cervantes-Perez, F., Herrera, A., and García, M., "Modulatory effects on prey-recognition in amphibia: a theoretical 'experimental study'", in Neuroscience: from neural networks to artificial intelligence, Editors P. Rudoman, M.A. Arbib, F. Cervantes-Perez, and R. Romo, Springer Verlag Research Notes in Neural Computing vol 4, pp. 426-449, 1993.

[4] Weitzenfeld, A., "ASL: Hierarchy, Composition, Heterogeneity, and Multi-Granularity in Concurrent Object-Oriented Programming", Proceeding of the Workshop on Neural Architectures and Distributed AI: From Schema Assemblages to Neural Networks, Oct 19-20, USC, October 19-20, 1993.

[5] Weitzenfeld, A., Arbib, M.A., "NSL - Neural Simulation Language", in Neural Networks Simulation Environments, Editor J. Skrzypek, Kluwer, 1994.

[6] Arkin, R.C., "Motor Schema-Based Mobile Robot Navigation", International Journal of Robotics Research, Vol. 8, No. 4, August 1989, pp. 92-112, 1989.

[7] Calderas, C., Mármol, S., "Diseño e Implementación de un Sistema Distribuido Heterogéneo para la Extensión del Lenguaje de Modelos Teórico Esquemáticos ASL", ITAM Undergraduate Thesis, CANNES-TR-96-01, ITAM, México, Octubre 1996.

[8] Olivares, R., "Integración del Ambiente de Simulación de Robótica Neuroetológica: NSL/ASL/MissionLab", ITAM Undergraduate Thesis, CANNES-TR-97-02, ITAM, México, DF, Septiembre 1997.

[9] Flores, L.R., "Modulación de Tiempo Variable de la Elicitación de la Conducta de Captura de Presas en los Anfibios Anuros", UNAM Master Thesis, CANNES-TR-97-01, ITAM, Mexico, DF, Agosto 1997.

[10] Arkin, R.C., Cervantes-Perez, F., Weitzenfeld, A., "Ecological Robotics: A Schema-theoretic Approach", AAAI 96 Fall Symposium, Boston, MA, 1996.

[11] Arkin, R.C., Cervantes-Perez, F., and Weitzenfeld, A., "Ecological Robotics: A Schema-Theoretic Approach", to appear in "Intelligent Robots: Sensing, Modelling and Planning", Editors R.C.Bolles, H.Bunke, and H.Noltemeier, World Scientific, 1998.