solving real-world problems. Most companies fail in the first year, and yet despite having computers that were at first only perhaps half the speed of an Apple II, his company was successful, surviving 17 years before being acquired by Titan Systems, Inc. in 1982.

During this time, Larry not only ran his company, but also founded a new journal, the *Journal of Cybernetics* (a predecessor to today's *Cybernetics and Systems*), taught a variety of courses at colleges in San Diego, California, and served on panels for the U.S. government. His keen insights were appreciated by many people.

One of Larry's greatest gifts was the gift of lecturing. He was a master. I have heard many stories from people who had seen him lecture in years past, with each maintaining a vivid memory of the event. Part of his talent was a natural enthusiasm and passion for what he was doing, and he wanted to share those feelings with the audience. I regret not seeing him finish one of his lectures with his characteristic singing of Cole Porter's "Experiment." Larry was both a scientist and orator, but he was also an entertainer.

Larry continued to advance evolutionary computation throughout his time at Titan Systems, Inc. (1984–1987), while starting his son David on the same path. Larry and David continued working together at another company, ORINCON Corporation, for five years (1988–1993) before leaving to start Natural Selection, Inc., which continues now as one of the leading companies in computational intelligence. The odds of starting two companies that last more than a decade are extremely small. The chance of success when starting a company at age 65 is also small. Larry accomplished both.

Warren S. McCulloch turns over the gavel of the presidency of the American Cybernetics Society to Larry Fogel on May 14, 1969 at a meeting in Toronto, Canada. Larry was the second president of ASC. Looking on from left to right are: Van Douglass, Alex Fraser (also a pioneer in evolutionary computation), and B. B. Goodfellow. (photo from ASC Newsletter, February 1970).

It was my great pleasure to have met Larry on a few occasions as part of my IEEE activities. His long record of distinction, including election as an IEEE Fellow (the first from the area of evolutionary computation), and recognition via the Evolutionary Programming Society's Lifetime Achievement Award, the SPIE Computational Intelligence Pioneer Award, the inaugural IEEE Neural Network Council's Evolutionary Computation Pioneer Award, and most recently the inaugural IEEE Frank Rosenblatt Technical Field Award, was well known to me. But what I remember most is his kindness, friendliness, open mindedness, curiosity, and confidence in the future.

Larry was an inspiration for all of us: we have lost a great friend, but we will always have a great example to follow.

In Memoriam—Reflections on Larry Fogel at Decision Science, Inc. (1965–1982)

Larry Fogel–A Lucky Combination of Natural and Artificial Intelligence, and Humanity

George Burgin,
Natural Selection, Inc., USA

This article consists of two parts: In a first section, I offer some reminiscences about my work with Larry (and his coworkers, Al Owens and Jack Walsh) while Larry was president of Decision Science, Inc. (DSI). Our common work was centered on evolutionary programming: its application to multiplayer games (such as air-to-air combat and missile evasion tactics), analysis of time series, system identification, and similar areas. In a second, shorter section, I will jump some 40 years forward in time from the early days of DSI to the very last days of Larry's life, when we worked together

Digital Object Identifier 10.1109/MCI.2007.913361

at Natural Selection, Inc., a company also co-founded by Larry in 1993.

My First Encounters with Larry

I first met Larry in the summer of 1962. I was managing a scientific "computer-service" bureau in Zurich, Switzerland equipped with a Bendix G-15 computer that had a magnetic drum as main memory and vacuum tubes as active elements. I attended an IFAC Congress in Munich, Germany where Larry presented a very impressive paper [1]. This was my first exposure to finite-state machines and to evolutionary programming. Three characteristics about Larry impressed me: (1) Larry's flair for performing experiments, (2) Larry's meticulous way of documenting his experiments, and (3) Larry's intelligence to draw significant conclusions from these experiments.

A few months after this Munich congress, I emigrated to the United States to work for General Dynamics in San Diego and was very excited to meet Larry again, *working for the same company!* I was performing research in numerical analysis. Larry, with his two colleagues, Al Owens and Jack Walsh, at this time did the ground-breaking, original research that subsequently formed the foundation for his famous book *Artificial Intelligence Through Simulated Evolution* [2]. Larry also had the good fortune of working with his father Aaron "Al" Fogel while at General Dynamics, testing systems reliability and inventing instrumentation.

In September 1965, Larry founded the first company in this field, Decision Science, Inc. I was fortunate to be asked by Larry, Al, and Jack to join this young company. One of my very first assignments was to assist Larry in proofreading the galley proofs of the aforementioned book [2], a most desirable and pleasant work experience.

The Adaptive Maneuvering Logic

Larry's fame at that time was not only based on his innovative evolutionary programming, but also on his invention of the "Kinalog," an aircraft cockpit display that allowed the pilot to obtain a better situational awareness of his predicted position and attitude. Larry was issued a U.S. Patent on this invention of an "Advanced flight control instrumentation and control system." The combination of artificial intelligence with a thorough understanding of the psychological and physiological processes that eventually determine the proficiency of a fighter pilot were recognized by leading engineers at the NASA Langley Research Center (LRC). LRC had just completed the construction of an extremely realistic flight simulator with two 40-feet diameter projection spheres including two cockpits, two projection systems with associated image generators, and a real-time computer system implemented on a CDC 6600 computer (at that time, one of the world's most advanced digital computer systems). LRC called this advanced flight simulator the Differential Maneuvering Simulator (DMS). LRC recognized early on that the utility of the DMS could be enhanced greatly if one of the two displayed aircraft was not controlled by a human pilot, but by an intelligent, interactive, computer program. The managers responsible for the operation of the DMS invited Larry to present a proposal outlining how a computer program for such an intelligently interactive opponent—an Adaptive Maneuvering Logic (AML)—could be designed.

DSI's proposal was accepted and funded. It formed the foundation for a longstanding close cooperation between LRC and DSI. Larry quickly developed a personal friendship with Patrick Gainer at LRC. Pat was instrumental in getting DSI's code to run on the DMS. Pat also was an accomplished musician, like Larry. On many trips to Langley, Larry carried his flute along—not just any ordinary silver flute—but one made of gold. After a day of hard work, Larry would join Pat at his home for an evening of classical music. This added to my admiration for Larry. During the entire DSI/LRC/AML cooperative effort, Larry's skill of communicating not only with engineers, but equally well with fighter pilots, contributed significantly to the success of this project. Larry's leadership and encouragement during rough times were exemplary, and this period of cooperation between Larry (the innovator) and me (the implementor) will remain one of the fondest memories of my entire professional career. During the development of AML, Larry, Pat, and I worked with many fighter pilots, and each of these

Larry Fogel (seated) and his father Al Fogel (right) testing cockpit instrumentation systems and reliability in the early 1960s at Convair, a division of General Dynamics in San Diego, California.

pilots gave freely and selflessly of their time and knowledge. I might mention here that the AML really achieved a level of proficiency that impressed pilots, even at the level of an accomplished U.S. Navy Blue Angels pilot [3].

Competitive Goal-Seeking Through Evolutionary Programming

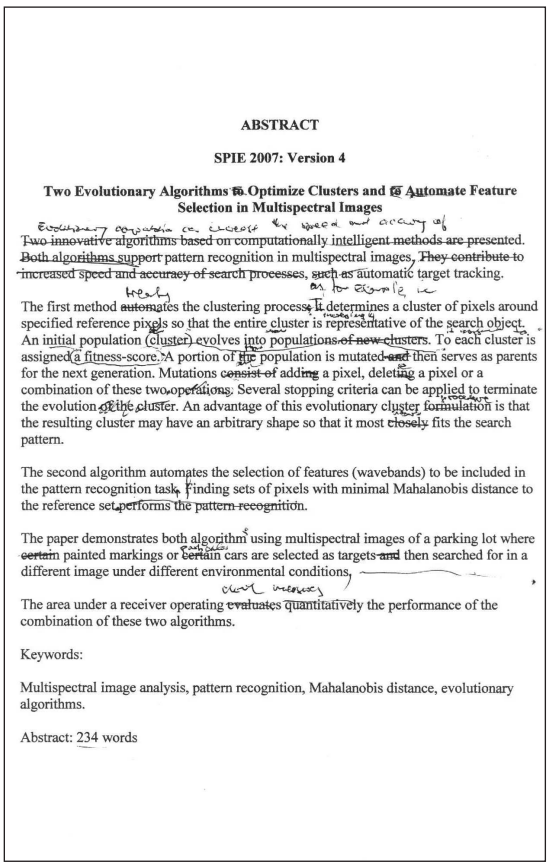
It comes as no surprise that Larry quickly recognized that techniques to pursue an enemy fighter plane should be approximately the opposite of the techniques to avoid an attacking missile, either one fired from the ground or fired by another fighter plane. Both problems fall into the class of competitive goal-seeking.

One of Larry's major contributions to computational intelligence was the combination of evolutionary programming with his concept of a "Valuated State Space"® (VSS). The VSS approach (now a registered trademark to Natural Selection, Inc.) forces the researcher to clearly define, in a quantitative, measurable form the degree of achievement of alternative solutions to a complex optimization problem. It requires defining, in a hierarchically organized structure, the parameters that contribute (with varying weights and normalizing functions) to the overall worth of a proposed solution.

Larry's good friend, Col. Barton Krawetz, then at Nellis Air Force Base, in Nevada, also immediately recognized the potential of using a combination of the Valuated State Space® approach and evolutionary programming for devising strategies for missile evasion. This concept provided a fine opportunity for Larry and me to work as a team to support the U.S. Air Force in developing tactics for missile evasion. We were again the innovator/implementor team. Larry never liked to be constrained in his thinking by such mundane problems as sensor availability and sensor performance or real-time execution of computer programs. His attitude always was: if it does not exist today, we will have it at some day in the future. The U.S. Air Force, on the other hand, was very much concerned with "What can we teach our pilots today that may save their lives tomorrow?" I think that Bart Krawetz (and his subordinates) appreciated our sincere efforts to come up with solutions that incorporated advanced artificial intelligence concepts yet were constrained by real missile and aircraft dynamics, sensor capabilities, and computer performance.

System Identification for the NASA Flight Research Center at Edwards, California

The good work performed by Larry and the DSI team for NASA LRC also opened the door to the NASA Flight Research Center (FRC) at Edwards Air Force Base, California; Larry was invited to give a lecture on "Evolutionary programming with applications to aerospace engineering problems." I felt lucky that Larry wanted me to accompany him for this lecture. Since we were early for our appointment at Edwards, I suggested to Larry that we might do some "rock-hounding" (the rock-collectors' expression for searching for rocks), looking for agates and petrified wood near Four Corners (North of San Bernardino, California). Typical for Larry, he was immediately enthused about such a new adventure. He was eager to learn quickly as much as possible about identifying and collecting rocks. Even though we did find some rather nice agates (that was about 40 years ago!), the trip did not transform Larry into a life-long rock-collector! Painstakingly searching for some "good" rocks in the vast Mojave desert did not provide enough "action" to keep Larry interested over any length of time. Nevertheless, the trip can be considered to have been a success: The engineers at FRC were so impressed with Larry's presentation that they rewarded us with a contract to apply evolutionary programming techniques to identify "system parameters" of the experimental X-15 aircraft [5].



ABSTRACT

SPIE 2007: Version 4

Two Evolutionary Algorithms to Optimize Clusters and to Automate Feature Selection in Multispectral Images

Two innovative algorithms based on computationally intelligent methods are presented. Both algorithms support pattern recognition in multispectral images. They contribute to increased speed and accuracy of search processes, such as automatic target tracking.

The first method automates the clustering process. It determines a cluster of pixels around specified reference pixels so that the entire cluster is representative of the search object. An initial population (cluster) evolves into populations of new clusters. To each cluster is assigned a fitness-score. A portion of the population is mutated and then serves as parents for the next generation. Mutations consist of adding a pixel, deleting a pixel or a combination of these two operations. Several stopping criteria can be applied to terminate the evolution of the cluster. An advantage of this evolutionary cluster formulation is that the resulting cluster may have an arbitrary shape so that it most closely fits the search pattern.

The second algorithm automates the selection of features (wavebands) to be included in the pattern recognition task. Finding sets of pixels with minimal Mahalanobis distance to the reference set performs the pattern recognition.

The paper demonstrates both algorithm using multispectral images of a parking lot where certain painted markings or certain cars are selected as targets and then searched for in a different image under different environmental conditions.

The area under a receiver operating evaluates quantitatively the performance of the combination of these two algorithms.

Keywords:

Multispectral image analysis, pattern recognition, Mahalanobis distance, evolutionary algorithms.

Abstract: 234 words

One of Larry's very last contributions to the computational intelligence community: Larry skillfully edited an abstract of a paper that I was ready to submit.

Polygraph Trace Identification

Larry's friendship with high-level government officials led to some interesting research for DSI. Larry's knowledge of human factors, combined with his background in electrical engineering, led to work in analyzing time histories obtained with polygraphs. One of the (then classified) projects that sustained DSI over several years was what we called the "SVNS" ("stress versus non stress") project. Due to the classified nature of this work, little or nothing was published. Today, we might categorize this work as research in "pattern recognition," a field that in the late 1960s and early 1970s was

much less developed than today. Larry did some truly pioneering work, using evolutionary programming to differentiate traces that exhibited stress versus traces that did not indicate that the subject was under stress.

Larry's Contribution During His Last Weeks

The examples presented so far reflect on my association with Larry and his company, DSI, more than 40 years ago. In the mean time, Larry became father of two sons, David and Gary. Both are accomplished scientists, very active in the computational intelligence community, a visible demonstration of the theory of evolution. I conclude this tribute to Larry with one final example of Larry's productiveness and helpfulness until a few weeks, almost a few days, before his passing away. I asked him to review an abstract of a paper I was ready to submit. Figure 2 shows Larry's edited version of my abstract. It not only demonstrates that Larry had "his way with words" (as Al Owens told me many years ago), but also that Larry would take such a simple task as editing an abstract seriously and by doing so provided me with his always much appreciated support.

I miss Larry.

References

[1] L.J. Fogel, "Toward Inductive Inference Automata," *Proceedings of the Congress, International Federation for Information Processing*, Munich, Aug. 1962.

[2] L.J. Fogel, A.J. Owens and M.J. Walsh, *Artificial Intelligence Through Simulated Evolution*, John Wiley & Sons, Inc., New York, 1966.

[3] G.H. Burgin, L.J. Fogel, and J.P. Phelps, "An Adaptive Maneuvering Logic Computer Program for the Simulation of One-On-One Air-To-Air Combat." NASA Contractor Report NASA CR-2582, Washington, D.C., 1975.

[4] L.J. Fogel and G.H. Burgin, "Competitive Goal-Seeking through Evolutionary Programming," Final Report on Contract No. AF 19 (628)-5927, Feb. 1969.

[5] G.H. Burgin, "Systems Identification by Quasilinearization and by Evolutionary Programming," *Journal of Cybernetics*, pp. 56–75, 1973.

In Memoriam—Reflections on Larry Fogel at The Titan Corporation (1982–1988)

The Expert Behind the Evolution

Gene W. Ray,
GMT Ventures, USA

While Dr. Larry Fogel was working for The Titan Corporation during the six years from 1982–1988, I had the pleasure of interacting with him at least weekly, if not daily as CEO. His unique knowledge and expertise provided numerous innovative solutions to problems considered critical to national defense. As an example of his vision and expertise, back in the early 1980's he and his colleagues at Decision Science, Inc. developed a simulator for training U.S. Air Force pilots in air-to-air combat. The objective of the simulator was to train pilots to be able to successfully engage and defeat the most capable adversary. The simulator was so effective, that the pilots simply could not succeed in their mission. The simulator that Larry helped develop performed that well. Larry had to go back to the drawing board and degrade the effectiveness of the simulator in order to allow the pilots to become adept and occasionally experience success in their undertaking. This is but one of the numerous contributions Larry made in the field of evolutionary computation.

Let me continue by saying that while Larry's numerous contributions to the field of evolutionary computation are well known and documented, what I would like to focus on is what I believe to be Larry's greatest accomplishment; one that may not be as widely known. That accomplishment is the creation of a wonderful family that will carry on Larry's legacy for years to come.

Larry created two companies over time. The second, Natural Selection Inc., was founded in 1993 as a family venture with his wife Eva and son David, and later, also including their other son Gary. Today it is a very successful company that is applying the technology Larry pioneered, to discover solutions to problems of national importance. Eva, David, and Gary

Larry and his wife Eva with their sons David (left) and Gary (right) in 1987.

Digital Object Identifier 10.1109/MCI.2007.913362