Yoram Baram's Scientific Milestones

1976, Baram's PhD thesis at MIT, "Information, Consistent Estimation and Dynamic System Idenfification" was the first to suggest the use of information proximity measures for wide control regimes ("Baram Proximity Measure – BPM" was noted at length by MIT Prof. Emeritus Michael Athans in his keynote lecture at the opening of the 2005 International Federation of Automatic Control World Congress in Prague, Czech Republic. IFAC Congress is held once in three years with over 3000 participants).

1985, 1986, the following 2 papers, written in collaboration with Prof. Uri Shaked of Tel Aviv University, the recipient of the 2017 Israel Prize for Engineering Research, have mathematically established the conditions for minimal-order state estimation by linear feedback control systems:

Y. Baram and U. Shaked. Minimal Order Estimation of Multivariable Continuous-Time Stochastic Linear Systems. *IEEE Trans. on Automatic Control*, Vol. AC-30, No. 5, pp. 483-484, May 1985.

Y. Baram and U. Shaked. Minimal Order Estimation of Multivariable Discrete-Time Stochastic Linear Systems. *SIAM J. on Control and Optimization*, Vol. 24, No. 4, pp. 817-820, July 1986.

1988, The following paper, written in collaboration with Prof. Thomas Kailath of Stanford University, Member of the US National Academy of Engineering and of the US National Academy of the Arts and Sciences, have mathematically established that closed-loop linear feedback control systems yield strictly smaller errors in estimation and control than open loop systems (these findings, which are fundamental to control theory, underlie the later realization by Baram that closed-loop feedback in neurologically impaired gait entrainment is considerably safer and more effective than open-loop control):

Y. Baram and T. Kailath. Estimability and Regulability of Linear Systems. *IEEE Trans. on Automatic Control*, vol. AC-33, no. 12, pp. 1116-1121, December 1988.

1986-1988 and 1996-1997, Baram has spent two sabbatical terms as a Senior Research Associate of the US National Research Council at the NASA Ames Research Center in Moffett Field, California, at the invitation of Profs. Heinz Erzberger and Dallas Denery, first investigating issues of control theory, then developing a visual "Nap of the Earth" helicopter navigation concept.

1996,1999, The following two papers have helped establish a theory of feedback control interaction between movement and vision, setting the ground for nearly two decades of subsequent technological development and collaboration with medical experts towards gait improvement in the neurologically impaired:

Y. Baram. A Bird's Eye View on the Descent Trajectory. IEEE Trans. on Aerospace and Electronic Systems,Vol. 32, No. 3, pp. 1085–1087, July 1996.

Y. Baram. Walking on Tiles. Neural Processing Letters, Vol. 10, No. 2, pp. 81-87, October 1999.

1999, The manifold stochastic dynamics method for Bayesian learning was one of only 25 works selected for full oral presentation out of over 600 papers submitted to 1999 NIPS (Neural Information Processing Systems – the most prestigious and selective conference in the field). Published later in the following paper with Baram's Ph.D. student, Mark Zlochin:

M. Zlochin and Y. Baram. Manifold Stochastic Dynamics for Bayesian Learning. Neural Computation, Vol. 13, pp. 2549-2572, 2001.

2000, Baram's preliminary work on gait improvement in the neurologically impaired by virtual reality feedback was the first of only three works noted for their significance by the Evaluation Committee, appointed by the Technion President to assess the international standing and the research and study programs of the Faculty of Computer Science (Profs. R. Karp, and A. Pnueli, winners of the Turing award, and Prof. R. E. Bryant) "The Technion Faculty of Computer Science," Report of the Review Committee, submitted to the President of the Technion on May 7, 2000).

2001, The following paper revealed the first results of clinical tests performed on Parkinson's disease patients at the Rambam Medical Center in Haifa, Israel, showing considerably improved gait performance by closed-loop visual feedback with respect to open-loop visual gait entrainment. It preceded tens of subsequent studies of gait improvement by closed-loop visual and auditory feedback in patient with various neurological disorders, published in leading medical journals.

Y. Baram, J. Aharon-Peretz, Y. Simionovici, L. Ron. Walking on Virtual Tiles. Neural Processing Letters, Vol. 16, pp. 227 – 233, 2002.

2001, The above results were also revealed in platform presentation by Baram at the 53rd Annual Meeting of the American Academy of Neurology, Philadelphia, 2001, a meeting attended by 12,000 neurologists from around the world. They were then widely publicized by a large host of world-wide media.

2004, Baram was granted a US patent (No. 6,734,834-B-1) for "Closed-loop Augmented Reality Apparatus"

2006, The following paper, reporting clinical test results of patients with multiple sclerosis, showing considerably improved gait performance by the use of the closed-loop visual feedback device at the "Carmel" hospital in Haifa, Israel, was published in the leading medical journal "Neurology":

Y. Baram and A. Miller. Virtual Reality Cues for Improvement of Gait in Multiple Sclerosis Patients. Neurology, 66;178-181, January, 2006.

2006, Following his lecture at the main annual conference on multiple sclerosis (CMSC – Conference of Multiple Sclerosis Center) in Orlando Florida, Baram was awarded the "Research Award for the Best Platform Presentation in Research in Multiple Sclerosis" for "Effects of Virtual Reality Cues on Gait in Multiple Sclerosis Patients". The plaque is displayed below:

2006, Baram was appointed the incumbent of the Technion's Roy Mattas/Winnipeg Chair in Biomedical Engineering.

2006-2007, Baram was invited by Prof. Alberto Espay of the Neurology Department of Cincinnati University Medical School to spend a sabbatical year there. Clinical and at-home tests of Parkinson's patients performed with Prof. Espay's team have shown considerable gait improvement in patient using the virtual reality device. Long-term positive effects were found in patients training with the device at home for several days. These test results were published in the following paper:

A. J. Espay, Y. Baram, A. K. Dwivedi, R. Shukla, M. Gartner, L. Gaines, A. P. Duker, F. J. Revilla. At-home training with closed-loop augmented-reality cueing device for improvement of gait in patients with Parkinson's disease. Journal of Rehabilitation Research & Development (JRRD) Vol. 47, No. 6, pp. 573-582, 2010.

2009, Joint clinical tests of patients with idiopathic senile gait disorders and patient with history of strokes using the audio-visual feedback device were performed by Baram with Prof. Judith Aharon-Peretz of the Technion Medical School and Dr. Ruben Lenger of the Fliman Geriatric Hospital in Haifa, Israel. Positive gait improvement results were obtained and reported in the following paper:

Y. Baram, J. Aharon-Peretz, Ruben Lenger. Virtual Reality Feedback for Gait Improvement in Patients with Idiopathic Senile Gait Disorders and in Patient with History of strokes. Journal of the American Geriatrics Society, Volume 58 Issue 1, 191-192, January 2010.

2010, The advantage of glide-symmetric tiles geometry over transverse lines geometry in its implementation by virtual reality feedback was demonstrated by clinical tests of multiple sclerosis patients and shown to produce an increase of nearly 300% in walking speed and an increase of 80% in stride length, as published in the following paper:

Y. Baram, A. Miller. Glide-Symmetric locomotion reinforcement in patients with multiple sclerosis by visual feedback. Disability and Reabilitation: Assistive Technology;5(5):323-6. 2010.

2010, Gait improvement in children with cerebral palsy using visual and auditory feedback was tested jointly with Dr. Ruben Lenger of ILAN – Israel Foundation for Handicapped Children, Haifa, Israel and found to result in considerable gait improvement. The results were published in the following paper:

Y. Baram and R. Lenger. Gait improvement in patients with cerebral palsy by visual and auditory feedback. Neuromodulation, 15(1):48-52, Jan-Feb,2012.

2012, Associative memory by quantum set intersection employing Grover's search algorithm, yielding an exponential storage capacity, was published with Baram's PhD student, Tamer Salman, in the following paper:

T. Salman and Y. Baram. Quantum Set Intersection and its Application to Associative Memory. Journal of Machine Learning Research (JMLR) 13, 3177-3206, 2012.

2012, Baram was invited by Prof. Virginia de Sa of the University of California at San Diego (UCSD) to come there for a collaborative study of EEG recordings during walk with the visual feedback device in PD patients. The results were published in the following paper:

Velu, P. D., Mullen, T., Noh, E., Valdivia, M., Poizner, H., Baram, Y., de Sa, V. R. Effect of visual feedback on the occipito-parietal-motor network in Parkinsons disease patients with freezing of gait. Frontiers in Neurology, 4(209), 2013.

2013, The following paper was the first to map mathematically the entire set of different modes of neuronal firing sequences:

Y. Baram. Global Attractor Alphabet of Neural Firing Modes. Journal of Neurophysiology. Vol. 110, pp. 907-915, 2013.

2015, Following the request of the US-Israel Binational Science foundation, Baram has served as a panelist in the evaluation committee of research proposals in Computational Neurobiology held in Washington DC on March 9-10, 2015.

2015, The effects of auditory feedback on gait in Parkinson's patients were clinically tested and the results were published in the following paper:

Baram, Y., Aharon-Peretz, J., Badarny, S., Susel, Z. & Schlesinger, I. Closed-loop auditory feedback for the improvement of gait in patients with Parkinson's disease. J. Neurol. Sci. 363 (15), 104–106, 2016.

2016, Employing the range of time constants associated with firing rates corresponding to human developmental stages, Baram has derived mathematical and geometric maps in the form of cobweb diagrams, presented in the following papers:

Baram, Y. Developmental metaplasticity in neural circuit codes of firing and structure. Neural Networks 85: 182–196, 2017.

Baram, Y. Developmental metaplasticity in cortical codes of firing and structure. Atlas of Science: September 11, 2017.

2017, Employing the concepts of somatic and synaptic polarities, Baram has proposed a unified theory of cortical connectivity, activity and memory, published in the following paper:

Baram, Y. Circuit Polarity Effect of Cortical Connectivity, Activity, and Memory. Neural Computation 30 (11): 3037-3071, 2018.

2020, Following the request of the US-Israel Binational Science foundation, Baram has served, for a second time, as a panelist in the evaluation committee of research proposals in Computational Neurobiology held in Washington DC on March 9-10, 2020.

2020-2021, Combining mathematical properties of random graphs and prime numbers, Baram has produced a linguistic trilogy of neural circuit categories, memory capacity and neural circuit trees, published sequentially in the following papers:

Baram,Y. Primal categories of neural polarity codes. Cognitive Neurodynamics, 14(1), 125-135, 2020.

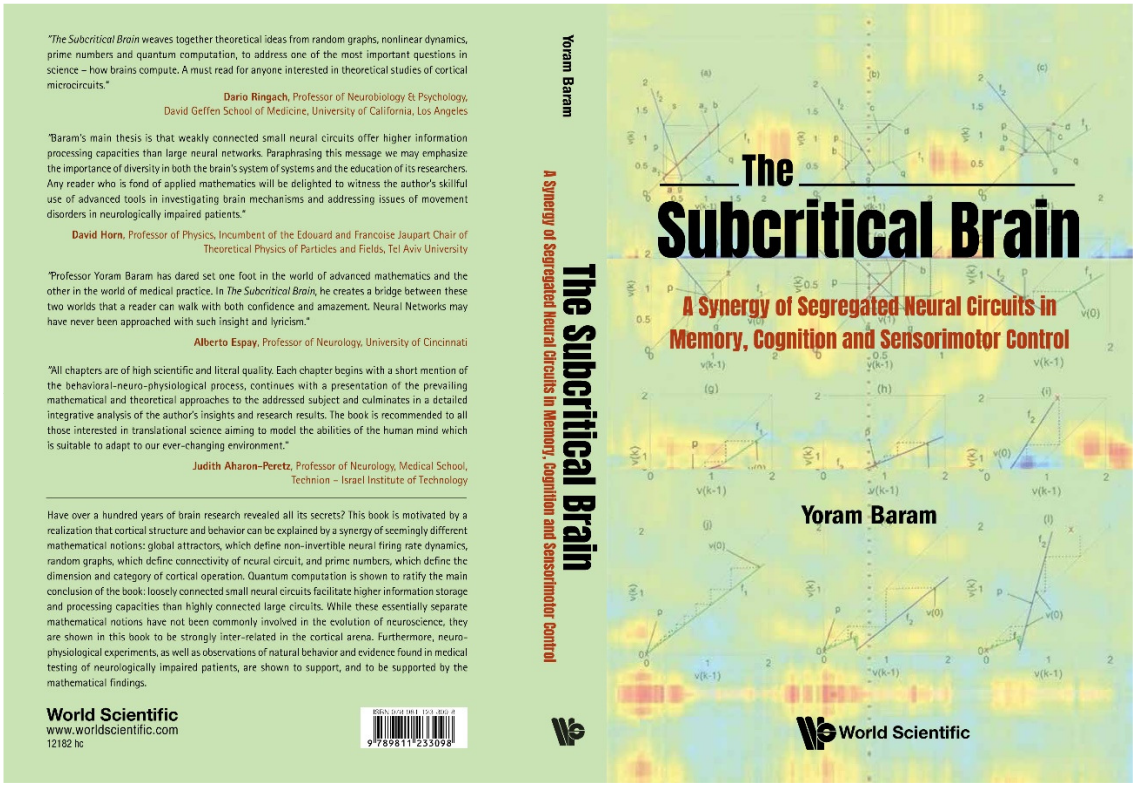
Baram,Y. Probabilistically segregated neural circuits and subcritical linguistics. Cognitive Neurodynamics,14(6), 837-848, 2020.

Baram,Y. Primal-size neural circuits in meta-periodic interaction. Cognitive Neurodynamics, 15(2), 359-367,2021.

2021, Baram's vision, streamlining graph theory, prime numbers, global attractors and quantum computation into coherent cortical operation, is presented in the book

"**The Subcritical Brain:** A Synergy of Segregated Neural Circuits in Memory, Cognition and Sensorimotor Control"

The book cover is displayed below:



Finally, it might be noted that in addition to the above-mentioned milestones, Baram's publications include many invited review and editorial papers, and large bodies of works in theoretical control theory, artificial neural networks, and theoretical neuroscience. These are listed in the "Publications" section of Baram's web site https://baram.net.technion.ac.il