Intelligent Strategies for Defense Systems
Tutorial (5h)

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The difficulties of modeling defense systems are related to adversarial reasoning. The main problem is to generate in real time intelligent predictive courses of action for all sides in a conflict. This problem is considered intractable by conventional approaches that suffer from the curse of dimensionality. Linguistic Geometry (LG), introduced in section 1of this tutorial, is a type of game theory scalable to modeling real world defense systems. LG allows us to overcome combinatorial explosion by changing the paradigm from search to construction (from analysis to synthesis). Modern applications of LG (see section 1), related to the US national defense, generate, in real time, courses of action that are highly creative and even exceed the level of those developed by human commanders. Currently, the U.S. Department of Defense is adopting the LG software to naval operations planning systems to command and control of infantry assault vehicles to missile defense testing, etc. All those advanced applications have been developed at STILMAN Advanced Strategies (STILMAN). Section 2 describes history of foundation, survival and expansion of this company.

In sections 3 and 4 of the tutorial, I will make a deeper dive into the topic of my keynote talk by introducing the audience to the structure of the Primary Language of the human brain following the ideas of J. von Neumann. In 1957, he suggested existence of the Primary Language as opposed to the Secondary (conventional) languages utilized for talking, reading and writing. According to our hypothesis, there should be algorithms based directly on the Primary Language. They were developed by humans subconsciously in ancient times. They include the Algorithm of Discovery (AD) utilized for all the discoveries and LG utilized for efficient warfighting. In sections 3 and 4, I will demonstrate manual application of the simulated AD for obtaining two results in LG. All the required information will be included in the tutorial.

Implementing Intelligent Strategies in Real World Systems

1. **From Ancient Warfare to Modern Adversarial Reasoning (1h).** In this section, going backward in history, I will introduce participants to several advanced applications of LG developed at STILMAN over the last 20 years. I will describe several US Army and DARPA experiments utilized those applications. Special emphasis will be made on the success of the DARPA RAID experiments, which was a variation of the Turing Test (whether it is true AI or not). A historical survey going forward will be related to the origin of LG, which is a mathematical

generalization of the no-search approach of a human expert to playing chess. I will introduce briefly the linguistic mathematical tools to explain the title of Linguistic Geometry. Further, I will also establish link between LG and legendary battles of Alexander the Great and Hannibal. Among other issues, I will introduce the hypothesis that LG is one of the ancient algorithms based directly on the Primary Language of the human brain.

2. **Turning University Research into the Real World Systems (1h).** In the USA, many research-oriented start-ups are the university spin-offs, i.e., they were originally created within the university's environment. I will describe chronologically the process of creation, survival, and subsequent take-off of such companies on example of STILMAN, the company created in 1999 as a spin-off of the University of Colorado at Denver. Intelligent software tools developed at STILMAN for the US Army beat all competition around the world and are considered vital for the US national defense. This lecture includes a comparison of roles of investors, competitive government contracts, large businesses, and foreign sources in obtaining working capital for small companies. The emphasis is on the US government system of competitive awards, especially, in defense, including SBIR (Small Business Innovation Research) as well as those from the federal agencies such as DARPA (Defense Advanced Research Agency), US Army, US Navy, etc. I will provide details of the relationship of a university and spin-off businesses. Special attention will be payed to the role of customers in developing new problem domains, theoretical ideas, and turning those ideas into working systems.

Automating Discovery of Intelligent Strategies

3. **Rediscovering Grammar of Shortest Trajectories (1h).** This section includes application of the AD to the development of the Grammar of Shortest Trajectories in LG. These trajectories are the planned routes over the Abstract Board to be taken by the Abstract Pieces to reach local goals. In LG, the trajectories are represented as strings of symbols while the grammar generating those strings is the Grammar of the Language of Shortest Trajectories. The AD constructs the grammar via several visual streams, which perform multiple thought experiments. One of the visual streams operating with the grammar symbols and utilizing other streams as procedure calls generates the actual grammar. Other streams execute those procedure calls and simultaneously develop algorithms of these procedures. In particular, one of the streams develops an algorithm for distance measurement over the Abstract Board. Another stream develops an algorithm for constructing the shortest route over the specific board of square cells and generalizes this construction for the Abstract Board.

4. **Rediscovering No-Search Approach (2h).** This section includes application of the AD to obtaining the major result in LG, an algorithm for constructing intelligent strategies for a class of games that involve mobile opposing entities. It is the so-called No-Search Approach. This approach shows that LG generates optimal solutions for a class of opposing games without search and demonstrates

construction of those solutions. As is the case with all other discoveries, the AD makes the discovery via a series of thought experiments, local and global. Local experiments on the chessboard establish foundation for the global ones over the entire game state space. The essence of this discovery is the efficient decomposition of the game state space. The AD implements decomposition via constructing a visual model of the state space called a State Space Chart. This Chart serves as a strategic “geographical map” of the state space by providing guidelines for “travel” from state to state. The AD uses this Chart for constructing classes of potential strategies for all the opposing sides and for pruning those classes that cannot be implemented for a given problem. The final step of the AD, application of the non-pruned potential strategies for “travel,” leads to construction of the optimal solution – the only real strategy existing in this problem.