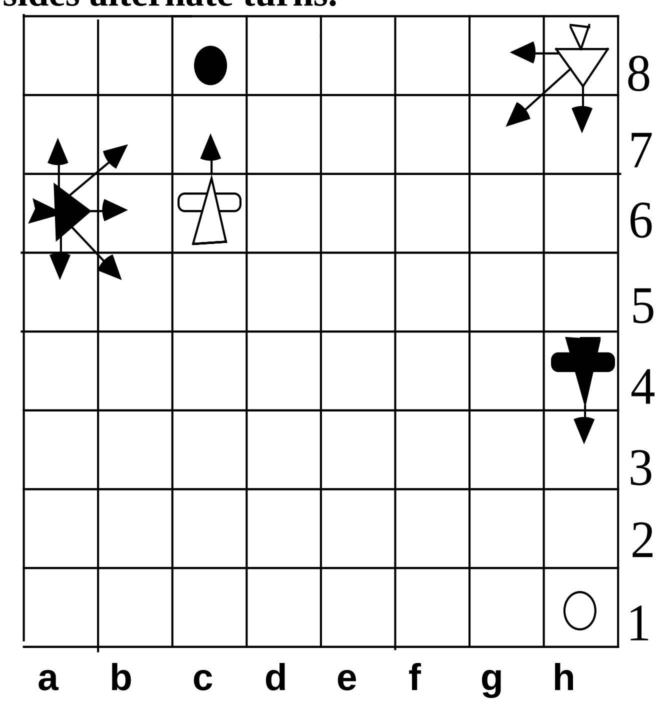
Linguistic Geometry

Assignment 1

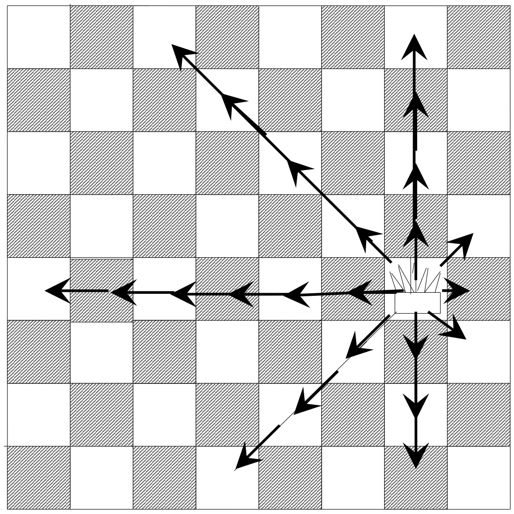
1. **Due Date: 08/28/17**

   Draw a "smart" search tree for the problem shown below and explain key moves employing diagrams with networks (be careful, compare with the 2D/4A problem shown in the next handout, see also Chapter 3 of the textbook). Assume that White begins and both sides alternate turns.



2. Due Date: 08/28/17

(a) Write down the general formula for the reachability relations $R_Q(x, y)$ for the Queen Q, which can move along diagonals, ranks and files (see below). Examples of reachability relations are given in this handout (p. 5) and in Section 2.2 of the textbook.



(b) Write down reachability formulas for the King and Night assuming that the chessboard is not a square but a cube of 8x8x8. Coordinates of a piece are determined by the coordinates of the little cube where this piece is currently located.

3. Project 1. Due 09/06/17

Write a program for computation of distances in ABG.

***Input*: set X (a 2D or 3D table with or without obstacles), an element p for which the distances should be calculated, location of the element, reachability relations for the element p (given as a formula or a small table).**

***Output*: a table of distances.**

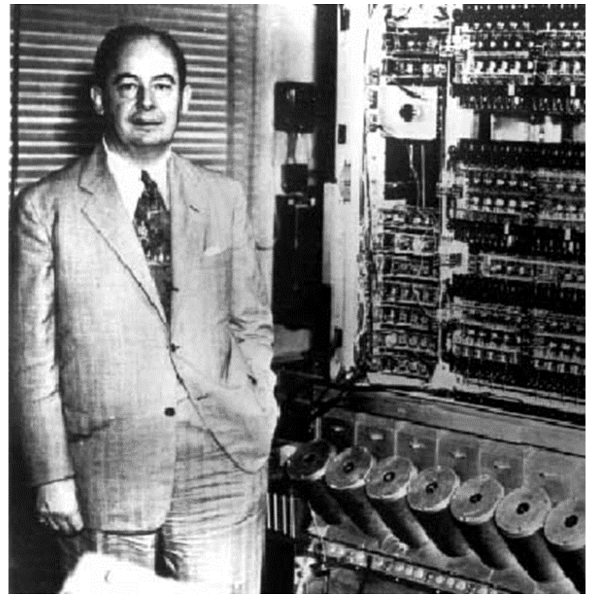
***Algorithm*: for the 8×8 set X without obstacles generate 15×15 tables and use them; for different X use direct computation.**

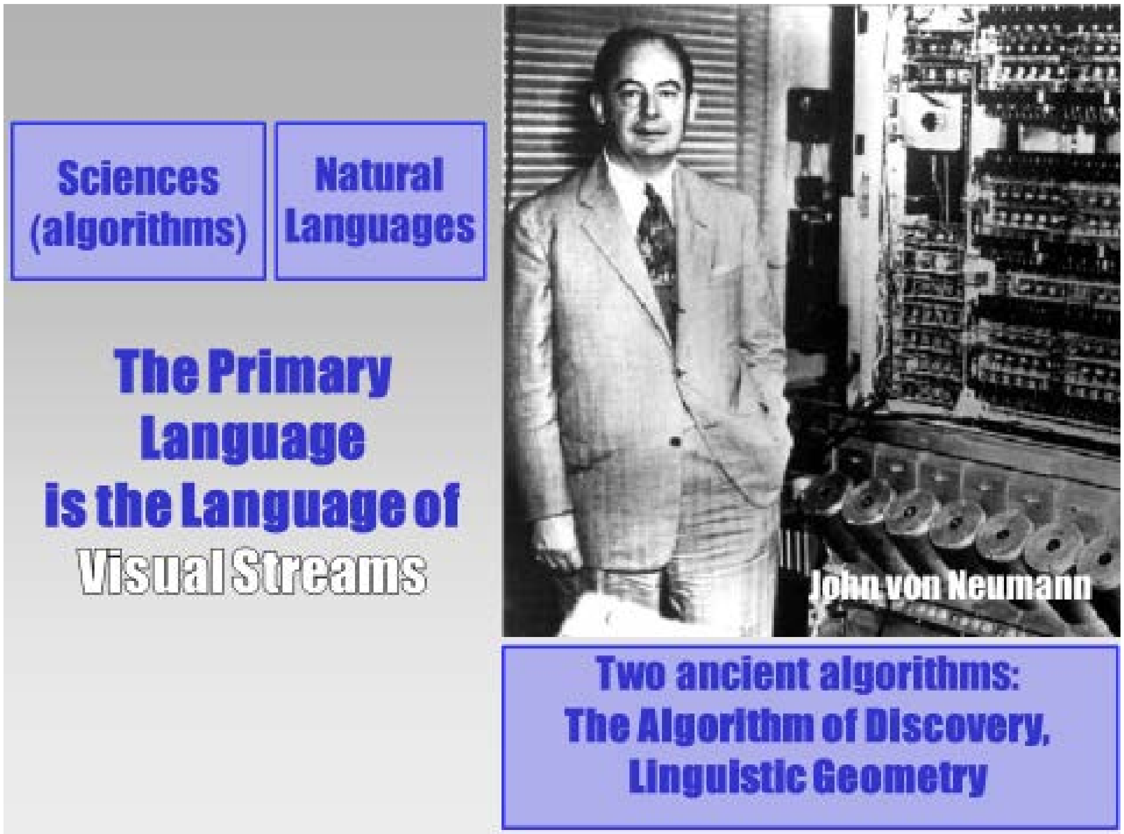
***Print* distances for sample locations for all the chess pieces (for 8x8 and larger) board with and without obstacles): Pawn (assume that Pawn can move straight ahead only), Knight, Bishop, Rook, Queen, and King. Print all your 15x15 tables.**

“It is only proper to realize that [human] language is largely an historical accident. The basic human languages are traditionally transmitted to us in various forms, but their very multiplicity proves that there is nothing absolute and necessary about them. Just as languages like Greek or Sanskrit are historical facts and not absolute logical necessities, it is only reasonable to assume that logics and mathematics are similarly historical, accidental forms of expression. They may have essential variants, i.e., they may exist in other forms than the ones to which we are accustomed. …

When we talk mathematics, we may be discussing a secondary language, built on the Primary Language truly used by the central nervous system.”

J. Von Neumann, 1957



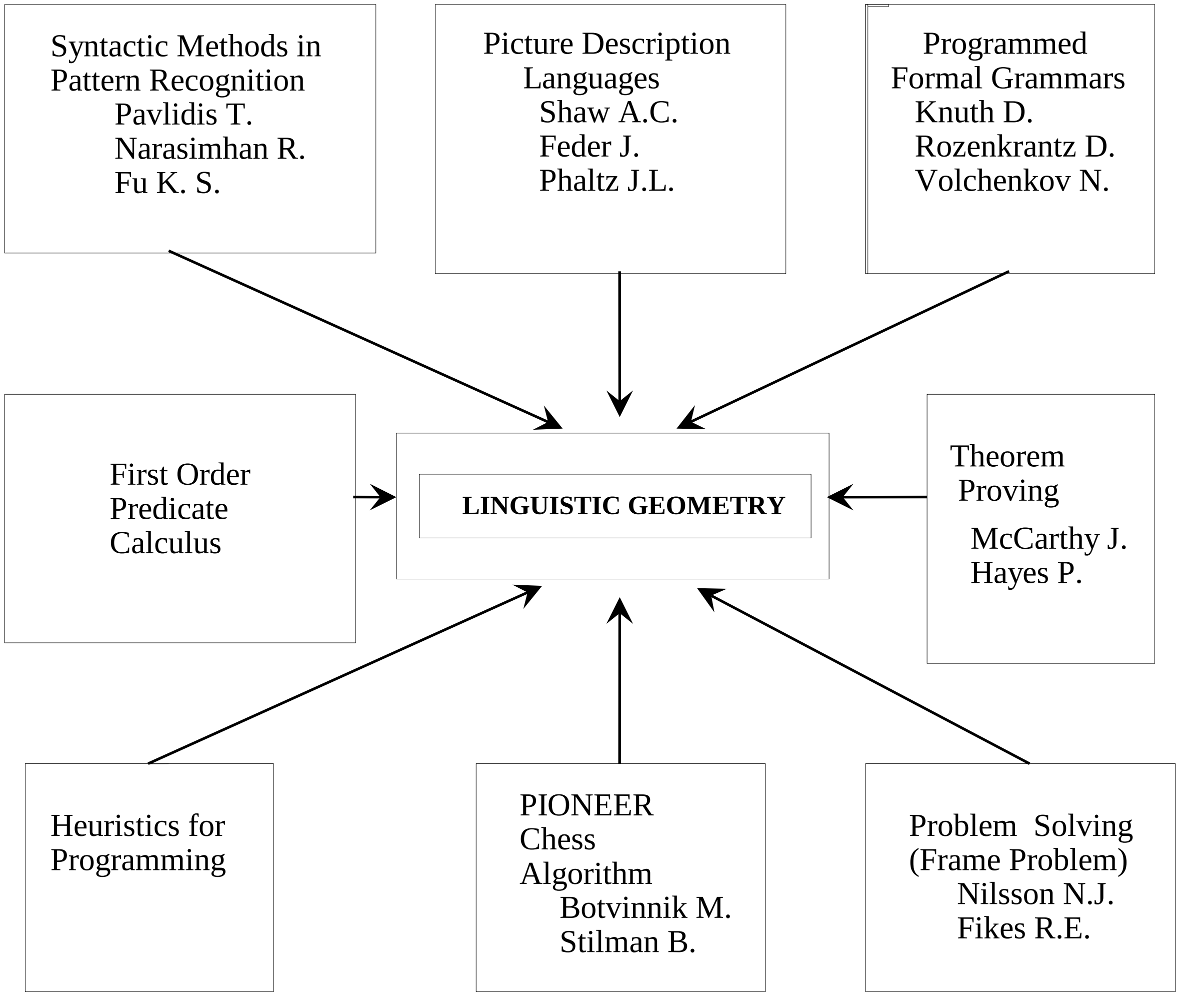

Sciences (algorithms)
Natural Languages
The Primary Language is the Language of Visual Streams
John von Neumann
Two ancient algorithms:
The Algorithm of Discovery,
Linguistic Geometry


1999
STILMAN
advanced strategies
www.stilman-strategies.com
Founded 9/9/99
in Denver, CO

Diversity of Applications

- Real time generation of potential COA and strategies
- Modeling intelligent adversaries and their reasoning
- Modeling military campaigns at various levels of resolution
- Situational awareness and predictive analysis
- Managing uncertainty, incomplete information and deception
- Smart sensors and communications
- Level 0-5 information fusion
- Resource allocation
- Distributed collaborative planning and execution
- Real time C2 and decision aids
- Uninhabited vehicles
- Post-mission analysis
- Training, mission rehearsal and rapid scenario generation
- Joint Operations
- Effect-Based Operations (EBO)
- Asymmetric Operations
- Military Ops in Urban Terrain (MOUT)
- Network-Centric Operations
- Simulation Based Acquisition (SBA)

Origin of Linguistic Geometry



Class of Problems

Abstract Board Game (ABG)
is the following eight-tuple

$$< X, P, R_p, \{ON\}, v, S_i, S_t, TR>$$

X = {x_i} is a finite set of ***points (or locations, cells)***;

P = {p_i} is a finite set of ***elements (or pieces)***; $\mathbf{P} = \mathbf{P_1} \cup \mathbf{P_2}$, $\mathbf{P_1} \cap \mathbf{P_2} = \varnothing$;

R_p(x, y) is a family of binary relations of ***reachability*** in X
($x \in X$, $y \in Y$, $p \in P$); y is ***reachable*** from x for p;

ON(p) = x is a partial function of ***placement*** of elements P into X;

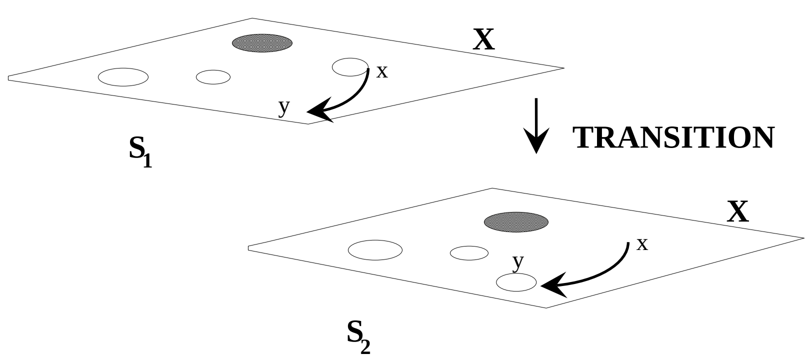
v > 0 is a real function, $v(p_i)$ are the ***values*** of elements;

S_i is a set of ***initial*** states of the system,
a certain set of formulas $\{ON(p_i) = x_i\}$;

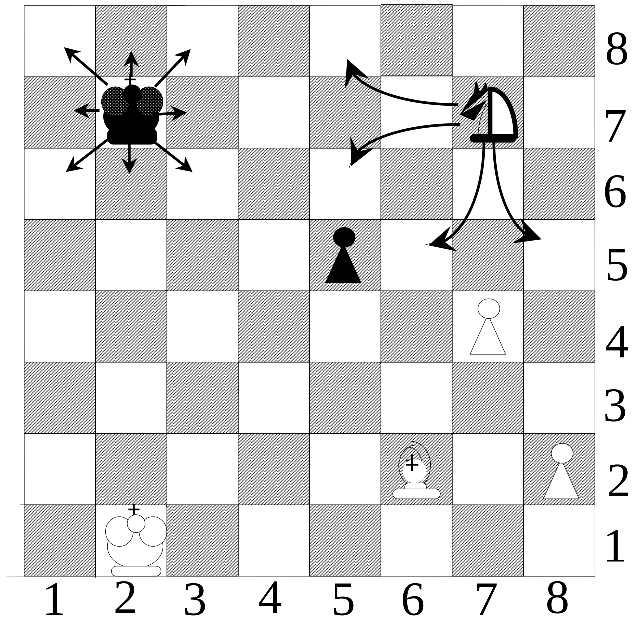
S_t is a set ***target*** states of the system (as S_i);

TR is a set of operators **TRANSITION(p, x, y)** for transition of the system from one state to another described as follows

precondition: $ON(p) = x \wedge R_p(x, y)$
delete: $ON(p) = x$, $ON(q) = y$
add: $ON(p) = y$



Chess Model as an ABG



KING: $R_K(x, y) = (x = (x_1, x_2) \wedge (1 \le x_1 \le 8) \wedge (1 \le x_2 \le 8)) \wedge$

$$(y = (y_1, y_2) \wedge (1 \le y_1 \le 8) \wedge (1 \le y_2 \le 8)) \wedge$$
$$(((y_1 = x_1+1) \wedge (y_2 = x_2)) \vee$$
$$((y_1 = x_1-1) \wedge (y_2 = x_2)) \vee$$
$$((y_1 = x_1) \wedge (y_2 = x_2+1)) \vee$$
$$((y_1 = x_1) \wedge (y_2 = x_2-1)) \vee$$
$$((y_1 = x_1+1) \wedge (y_2 = x_2+1)) \vee$$
$$((y_1 = x_1-1) \wedge (y_2 = x_2-1)) \vee$$
$$((y_1 = x_1+1) \wedge (y_2 = x_2-1)) \vee$$
$$((y_1 = x_1-1) \wedge (y_2 = x_2+1)))$$

$x \in Z\times Z, y \in Z\times Z$

Better:

$R_K(x, y) = (x = (x_1, x_2) \wedge (1 \le x_1 \le 8) \wedge (1 \le x_2 \le 8)) \wedge$

$$(y = (y_1, y_2) \wedge (1 \le y_1 \le 8) \wedge (1 \le y_2 \le 8)) \wedge$$
$$(|y_1-x_1| \le 1 \wedge |y_2-x_2| \le 1)$$

$x \in Z\times Z, y \in Z\times Z$

KNIGHT: $R_N(x, y) = (x = (x_1, x_2) \wedge (1 \le x_1 \le 8) \wedge (1 \le x_2 \le 8)) \wedge$

$x \in Z, y \in Z$ $\quad (y = (y_1, y_2) \wedge (1 \le y_1 \le 8) \wedge (1 \le y_2 \le 8)) \wedge$

$$
\begin{aligned}
&(((y_1 = x_1+2) \wedge (y_2 = x_2+1)) \vee \\
&((y_1 = x_1-2) \wedge (y_2 = x_2+1)) \vee \\
&((y_1 = x_1+2) \wedge (y_2 = x_2-1)) \vee \\
&((y_1 = x_1-2) \wedge (y_2 = x_2-1)) \vee \\
&((y_1 = x_1+1) \wedge (y_2 = x_2+2)) \vee \\
&((y_1 = x_1-1) \wedge (y_2 = x_2+2)) \vee \\
&((y_1 = x_1+1) \wedge (y_2 = x_2-2)) \vee \\
&((y_1 = x_1-1) \wedge (y_2 = x_2-2)))
\end{aligned}
$$

$x \in Z\times Z, y \in Z\times Z$

Better:

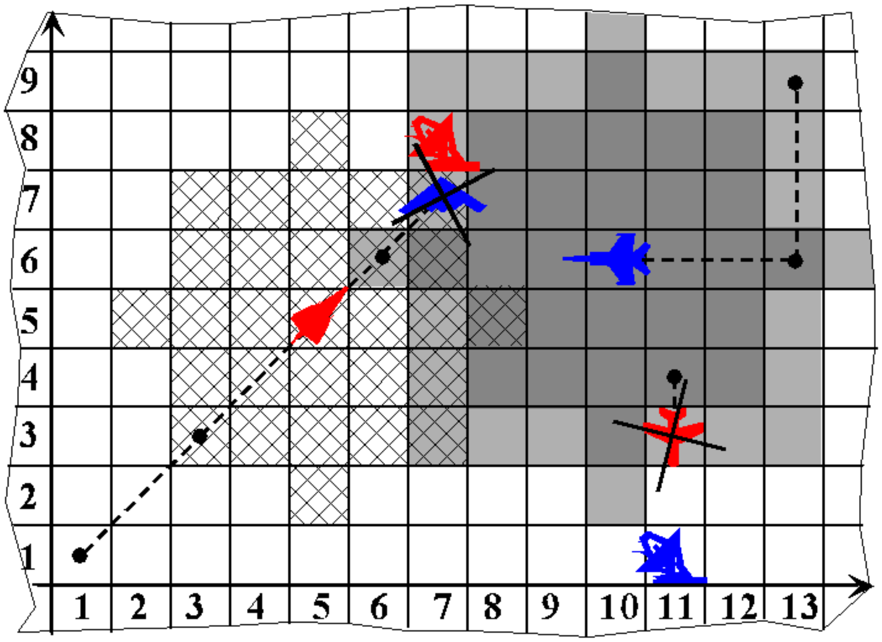
$$
\begin{aligned}
R_N(x, y) = \;&(x = (x_1, x_2) \wedge (1 \le x_1 \le 8) \wedge (1 \le x_2 \le 8)) \wedge \\
&(y = (y_1, y_2) \wedge (1 \le y_1 \le 8) \wedge (1 \le y_2 \le 8)) \wedge \\
&((|y_1-x_1| = 2 \wedge |y_2-x_2| = 1) \vee \\
&\;(|y_1-x_1| = 1 \wedge |y_2-x_2| = 2))
\end{aligned}
$$

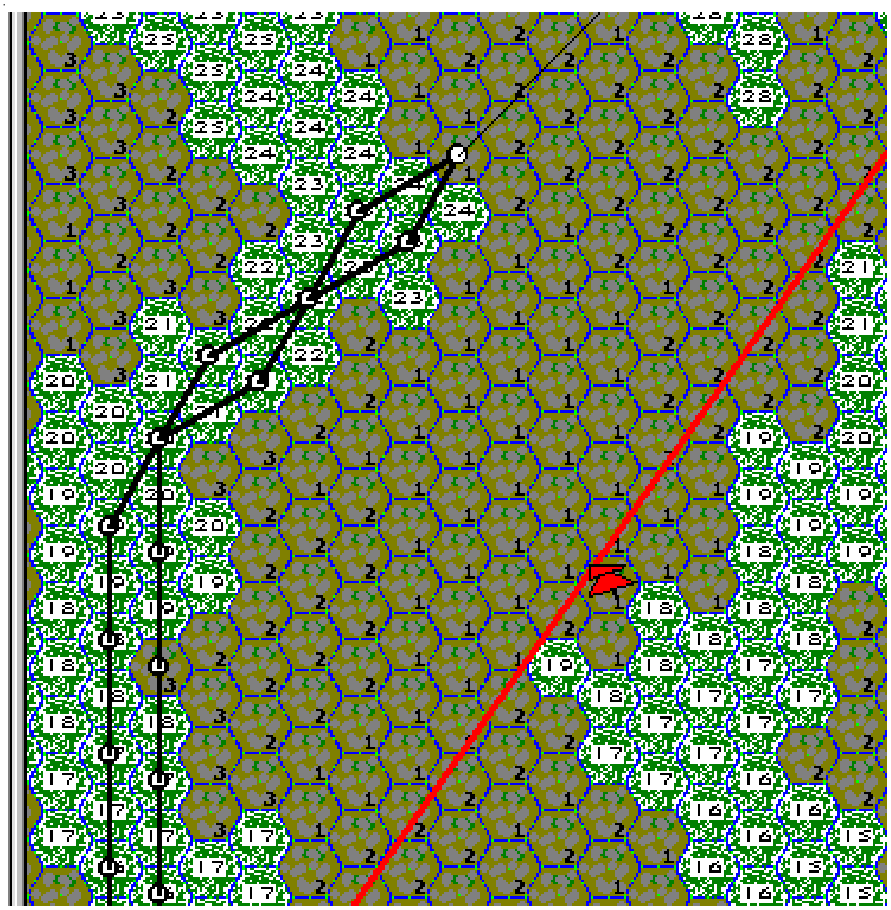
$x \in Z\times Z, y \in Z\times Z$

ABG: Problem Discretization

- ❑ Space Discretization (2D, 3D, Sphere)
- ❑ Piece Discretization
- ❑ Movement Discretization
  (Time; Mobility, Weapons, Sensors)

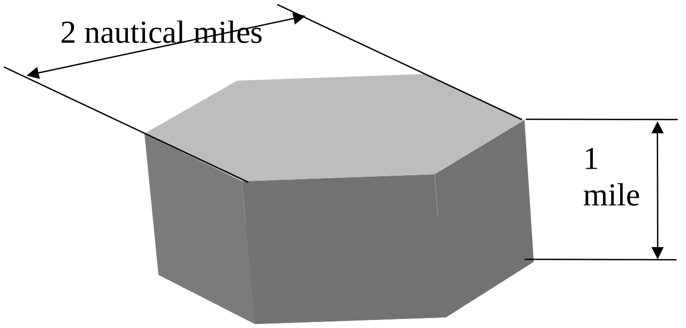
❑ Space Discretization



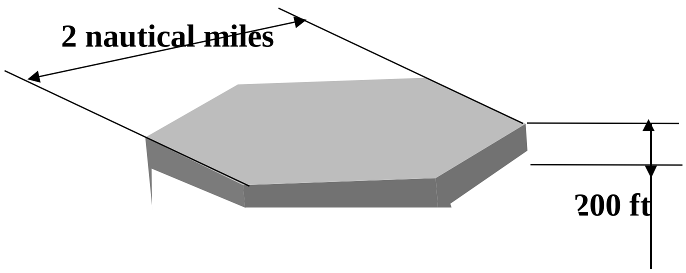


Space Discretization

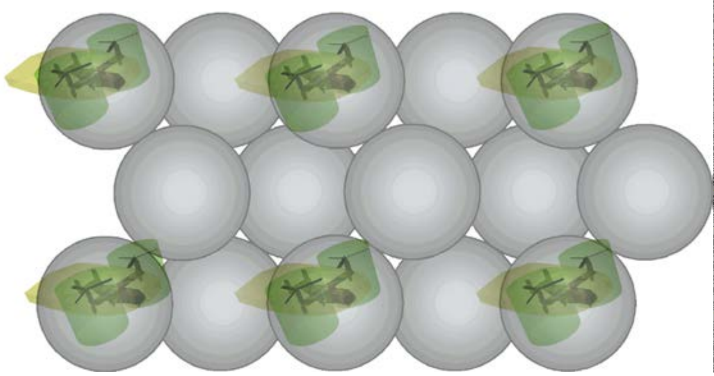
JFACC Cell

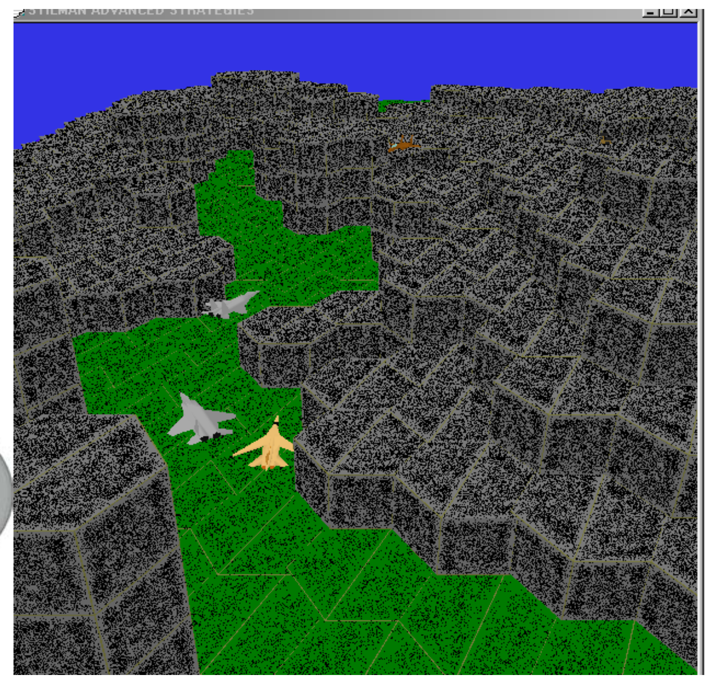


LG-PROTECTOR Cell



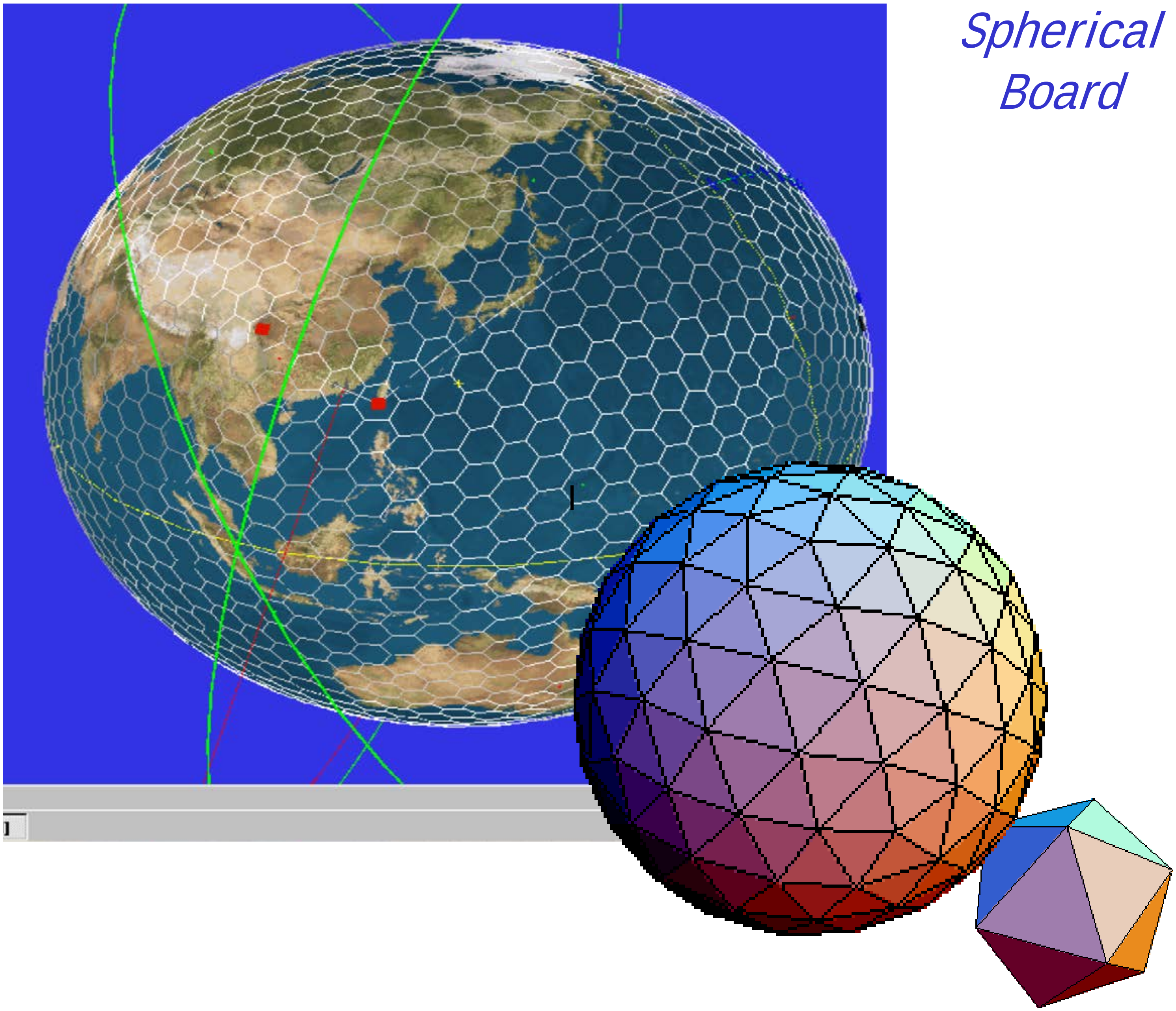
LG-ROTOCRAFT Cells



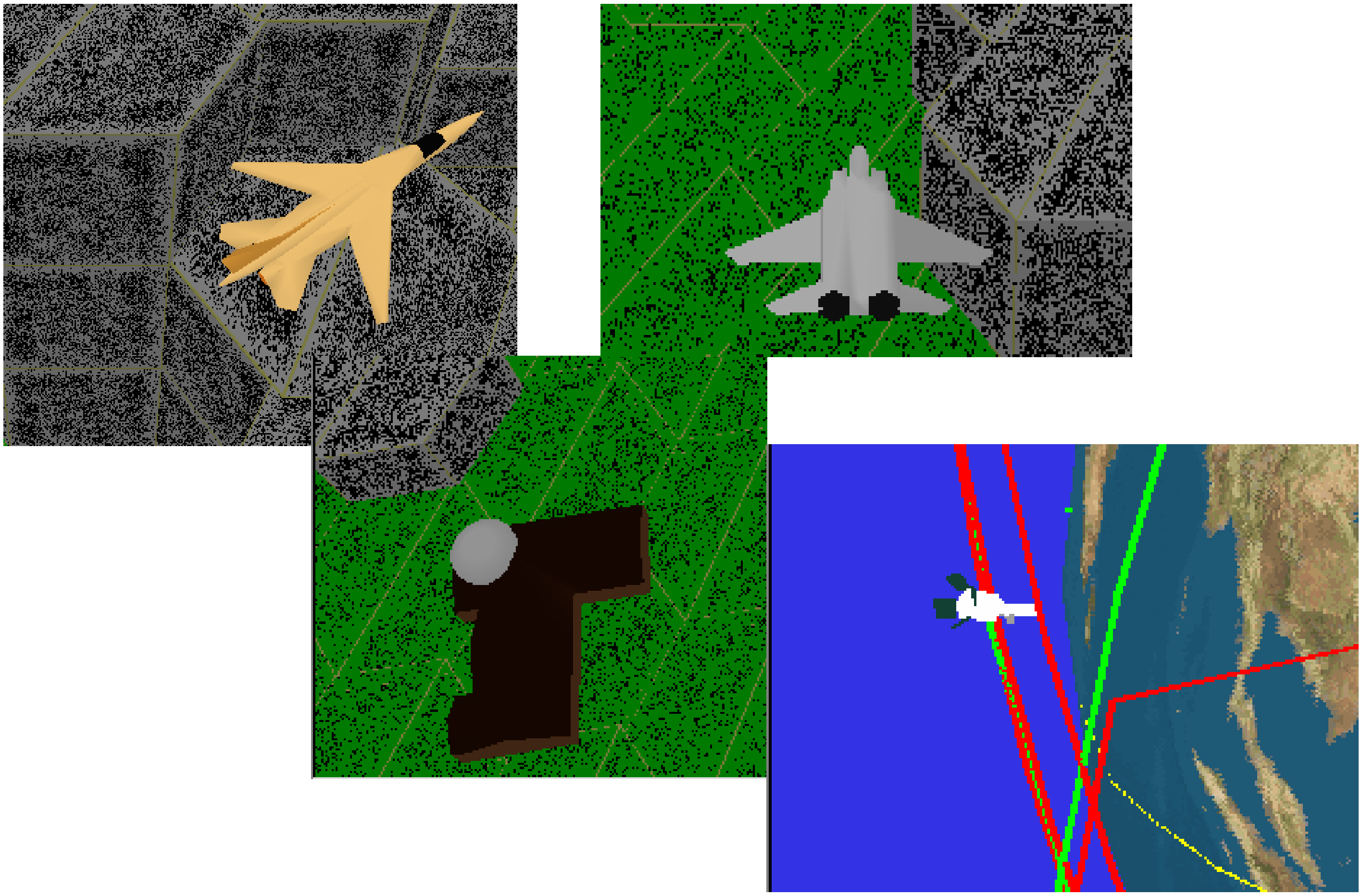


❑ Space Discretization

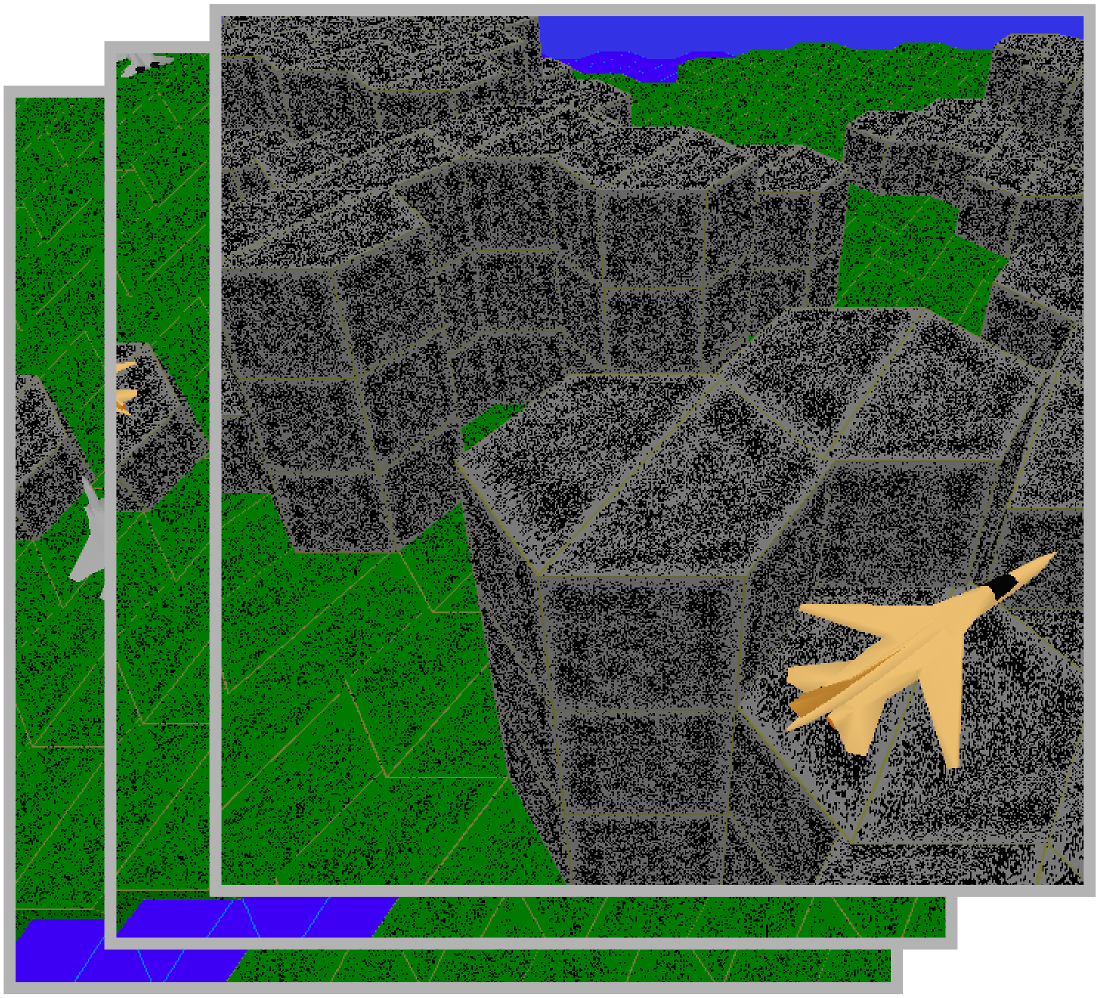
Global Spherical Board



❑ Piece Discretization



❑ Movement Discretization



Time Increment: 30 sec

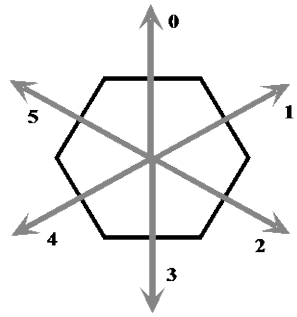
Other Increments:
1 min
30 min
1 day
. . .

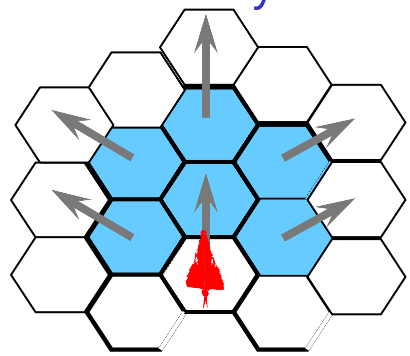
❑ Movement Discretization

Mobility

- ✓Velocity
- ✓Acceleration
- ✓Gravity
- ✓Terrain Following
- ✓Inertia
- ✓Orbit ?
- ✓Ballistic Flight ?

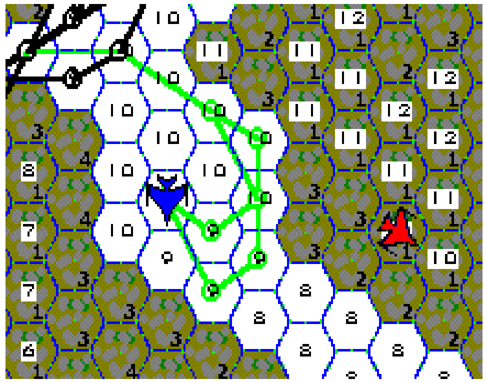
Relations of Reachability



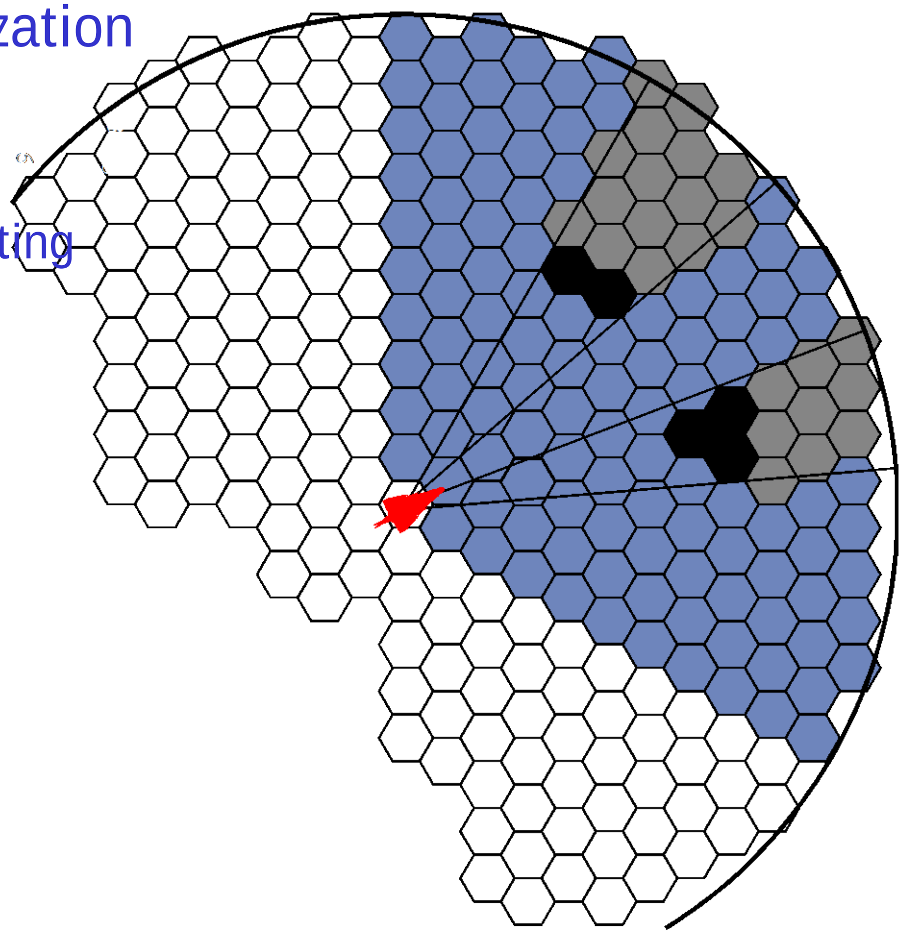


Direction space = {0,1,2,3,4,5}

Phase Space = 3D × Direction Space



❑ Movement Discretization



Weapons and Sensors

- ✓Long/Short Range Shooting
- ✓Multiple Weapons
- ✓Obstacles

- ✓Sensor Control
- ✓Radar Illumination
- ✓Laser Beam

- ✓Probabilistic Outcome

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