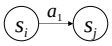
Sought-after features

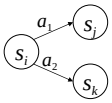
- open game world
- intelligent synthetic players
- multiplaying
- customization
- extensions
- replaying

Game progression as a graph

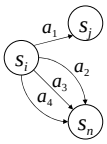
Linear



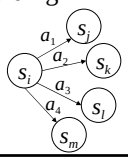
Forking



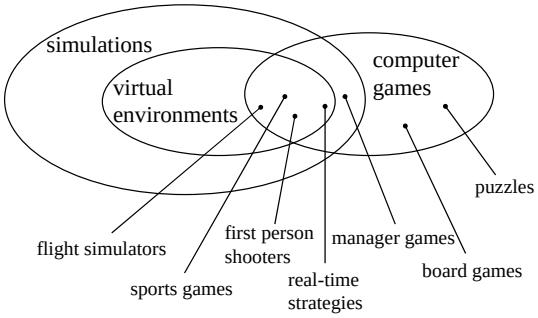
Conjoining



Unfolding



Simulations vs. computer games

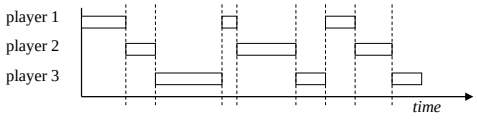


Key questions for synthetic players

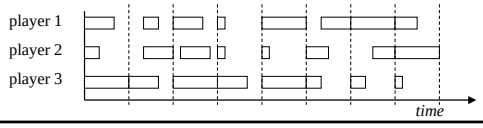
- how to achieve real-time response?
- how to distribute the synthetic players in a network?
- how autonomous the synthetic players should be?
- how to communicate with other synthetic players?

Interaction in a multiplayer game

Turn-based game



Real-time game



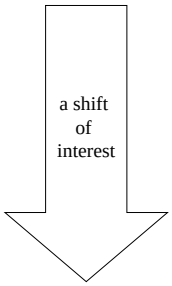
Sought-after features (revisited)

- open game world
- intelligent synthetic players
- multiplaying
- customization
- extensions
- replaying

→ parameterization!

Algorithmic problems in computer games

- graphics and audio
  - 3D rendering
  - camera movements
  - adaptive audio
- simulation and modeling
  - game engines
- multiplayer networking
  - protocols and security
  - resource distribution
- artificial intelligence (AI)
  - computer-controlled actors



Topics 1(2)

- Random Numbers
  - if computers are deterministic, how to achieve indeterminism at all?
- Game Trees
  - given time and resources, how to solve perfect information games?
- Path Finding
  - observing the geography of the game world, how to get from one place to another?

Topics 2(2)

- Decision-Making
  - being a synthetic participant on a game, how to interact?
- Cheating Prevention
  - if players are not trustworthy, how to ensure fairness?
- Code Tweaking
  - if feeling too clever by half, how to still code clever?

§2 Random Numbers

- what is randomness?
- linear congruential method
  - parameter choices
  - testing
- random shuffling
- uses in computer games

What are random numbers good for (according to D.E.K.)

- simulation
- sampling
- numerical analysis
- computer programming
- decision-making
- aesthetics
- recreation

Random numbers?

- there is no such thing as a 'random number'
  - is 42 a random number?
- definition: a sequence of statistically *independent* random numbers with a uniform *distribution*
  - numbers are obtained by chance
  - they have nothing to do with the other numbers in the sequence
- uniform distribution: each possible number is equally probable

Methods

- random selection
  - drawing balls out of a 'well ~~stirred~~ urn'
- tables of random digits
  - decimals from π
- generating data
  - white noise generators
  - cosmic background radiation
- computer programs?

Generating random numbers with arithmetic operations

- von Neumann (ca. 1946): middle square method
  - take the square of previous number and extract the middle digits
- example: four-digit numbers
  - $r_i = 8269$
  - $r_{i+1} = 3763$ ($r_i^2 = 68\underline{3763}61$)
  - $r_{i+2} = 1601$ ($r_{i+1}^2 = 14\underline{1601}69$)
  - $r_{i+3} = 5632$ ($r_{i+2}^2 = 25\underline{6320}1$)

Truly random numbers?

- each number is completely determined by its predecessor!
- sequence is not random but *appears to be*
- → pseudo-random numbers
- all random generators based arithmetic operation have their own in-built characteristic regularities
- hence, testing and analysis is required

Middle square (revisited)

- another example:
  - $r_i = 6100$
  - $r_{i+1} = 2100$ ($r_i^2 = 37\underline{2100}00$)
  - $r_{i+2} = 4100$ ($r_{i+1}^2 = 4\underline{4100}00$)
  - $r_{i+3} = 8100$ ($r_{i+2}^2 = 16\underline{8100}00$)
  - $r_{i+4} = 6100 = r_i$ ($r_{i+3}^2 = 65\underline{6100}00$)
- how to counteract?

Words of the wise

- 'random numbers should not be generated with a method chosen at random'
  — D. E. Knuth
- 'Any one who considers arithmetical methods of producing random digits is, of course, in a state of sin.'
  — J. von Neumann

Words of the more (or less) wise

- 'We guarantee that each number is random individually, but we don't guarantee that more than one of them is random.'
  — anonymous computer centre's programming consultant (quoted in *Numerical Recipes in C*)