How do you get good answers?

Garbage in, garbage out
- quality of input determines the quality of output
- universally accepted
- not universally true

How are you performing the simulation?
- do your equations make physical sense?
- do you understand the phenomenon?

Understanding and Direction Fields

Many simulations rely on differential equations
- Use a simple test to understand the behavior of the equation
- Does this behavior approximate reality?
- Which is wrong, reality or the equation?

Use simple, direct methodology to test assumptions EARLY
- Direction fields are merely a simple way to understand simple equations
- Start with a wide view of the problem and the proposed solution.

Direction Fields

When approximating a solution:
- Just calculating the slope of the line at any one point gives an increasingly inaccurate answer.

When approximating a solution:
- Euler’s method gives a much more satisfying fit than crude method.
- Predictor-corrector method: Use the average of the current slope and the next predicted point’s slope.
Garbage In, Garbage Out
- In some situations:
  - High fidelity data goes bad
- In other situations:
  - Low fidelity data makes good
  - Convergent direction fields effectively reduce error
  - Divergent direction fields effectively induce error

Directional Fields and Step-size
Using the predictor-corrector method:
- Optimize your solution
- Use current and predicted points' slopes
  - Too close, double step size
  - Too far, halve step size
- Different step-sizes in the same simulation

Straight-line vs. Polynomial Approximation
Euler used straight lines for approximation
- Simple, straight-forward
More likely today to use 4th degree polynomials
- Several points used to develop an equation
- The derivative of the equation at the point is the input
- The polynomial fit should be good, but it will not be exact and you will have “corners”

Recursive Digital Filter
Approximation by polynomials is equivalent to digital filter theory
- Sample several points
- Produce predicted value
- Make corrections
- Sample again…
But they are not the same!

Numerical Analysis vs. Filter Theory
Digital Filters deal in frequencies rather than equations
- No “corners” at the step transitions
- Fidelity may be lower
- The “feel” will be better

Which is Better?
Depends on what you’re simulating
- Mars lander
  - For the pilot—needs “feel”
- Mars voyage
  - For the physicist—needs fidelity
GIGO, Revisited

Nike missile testing
- Test failures in September 1946

Los Alamos atomic bomb calculations
- Estimates produce accurate results

Direction Fields, GIGO, and the Simulator

Not all situations can be reduced to a single, simple formula
- "[T]he whole computation must be understood as a whole"
- Is there a feedback compensation which occurs?
- Are there values which are "vitally" out in the open?
- Understanding offers protection from overkill
  - Don't need:
    - too many accurate values
    - too many precise components

Rorschach Test

A quest for meaning in the meaningless
- Inkblot test "reveal[s] things about yourself"
- A system's design and testing can just as easily reveal things about the engineer, and not the problem or the solution
- It is too easy to manipulate things in a simulation to get the expected results instead of "reality"
- As such, results are often called into question based on the assumptions which drive them, a process which allows more of the same to occur, not always less
- Double-blind experiments

Conclusions

“Simulation is essential to answer the ‘What if...?’, but it is full of danger...”
- Not to be trusted on its face
- Can be a tool of decisive action
- Can be a tool of waffling, delaying, and mediocrity
- Know what questions to ask
- Know what details to understand