Data Assurance in Opaque Computations

High Assurance Systems Engineering

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Topics

- Motivation
- Systems Engineering Cycle
  - Definition: the Problem Domain and the Systems Response
  - Computation
  - Management and use of the data created
- 'Matters Arising' in computations of Endgame Tables
- The Declarative Approach
  - The generic approach and benefits
  - HOL, Chess and BDDs
- The Future: Opportunities and Challenges for Assurance
  - Parallelism
  - Community Computing , e.g. The Chess Studies Community
- Summary

Motivation

- My interest in the endgame and in the use of EGTs
  - A concern for the future integrity of EGTs
  - The 'single thread' today is the Bourzutschky/Konoval partnership
- Mathematical Background:
  - 'Unto thyself be true, as the night followeth the day' (Laertes, Hamlet)
  - Theorems have integrity
  - A search for 'The Grail': Programs with the integrity of theorems
  - Research on Proving Programs Correct … Turing, 1949
  - 'Defensive' if not infallible programming' style
  - Rigorous approach in the '70s and '80s to
    - The Four Colour Conjecture, Mersenne Number testing
- Lifestyle globally and increasingly dependant on Systems
- Need for 'vehicles' to help teach Systems Engineering principles

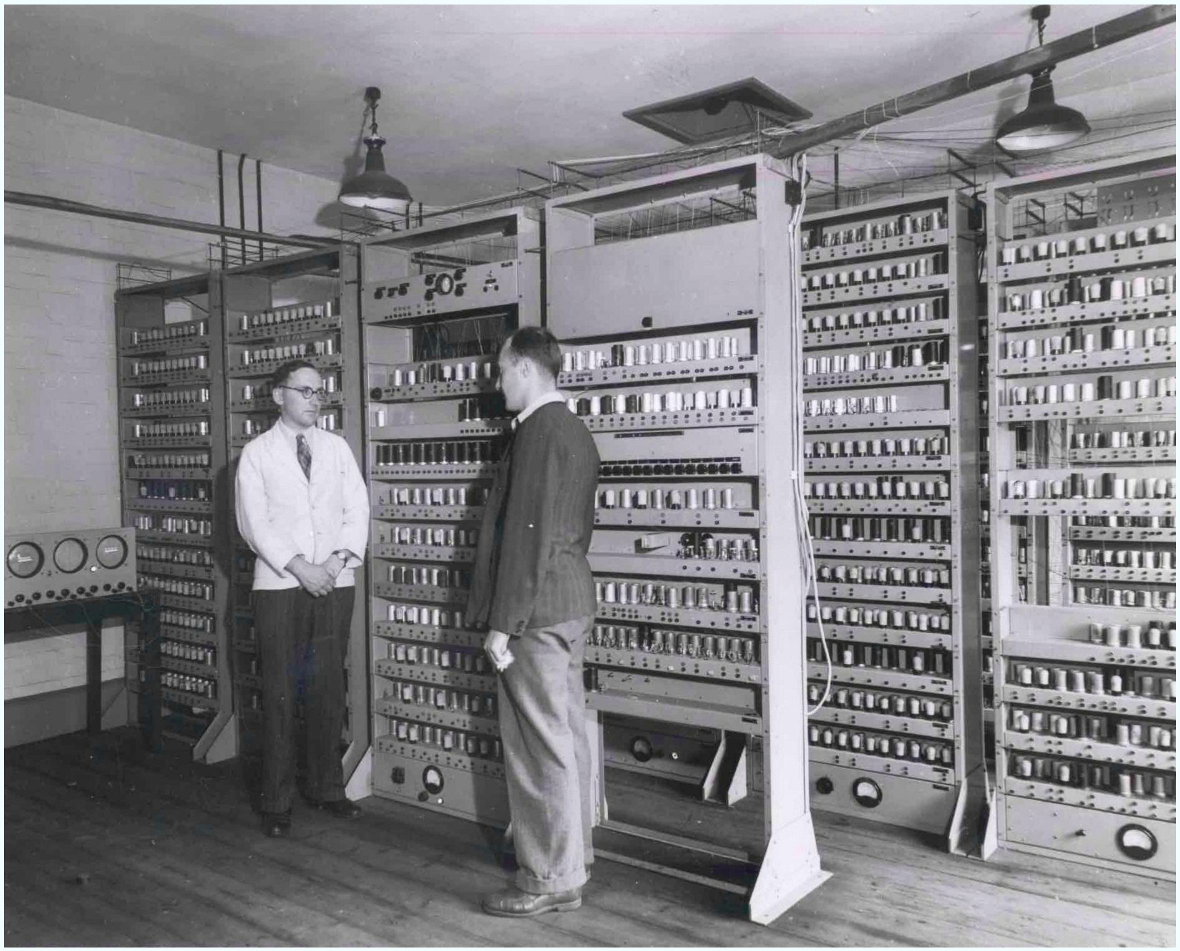
The Systems Engineering Cycle

- The Scenario and the 'System Response'
- Phase 1: Definition - the author
  - models the scenario of the computation
  - analyses the requirements and designs a systems response
  - Implements and tests the System Response
- Phase 2: Computation
  - the author runs the computation and generates output
- Phase 3: Use
  - the author manages the output: publishes, promulgates, comments
  - the reader uses and interprets the results of the computation

SEC Phase 1: Definition

- Translating 'real world' into a 'computer model' of same
- This task is eased by:
  - the simplicity of the scenario
  - complete knowledge about the scenario
  - the maturity of the translator: training, skill, experience
  - the method and tools used, esp. the target language
- Modelling failures arise:
  - 1.1: in setting up the initial 'static aspects' of the *scenario*
  - 1.2: in emulating the 'dynamic aspects' of the *process*
- 1.3: Inadequate testing:
  - Boundary problems, 'One out' problems
  - Testing only proves that bugs 'of certain types' do not exist

EDSAC I: First software bug



- **Maurice Wilkes:**

  "… the realisation came over me that a good part of the remainder of my life was going to be spent in finding the errors in my own programs."

  Memoirs, p145

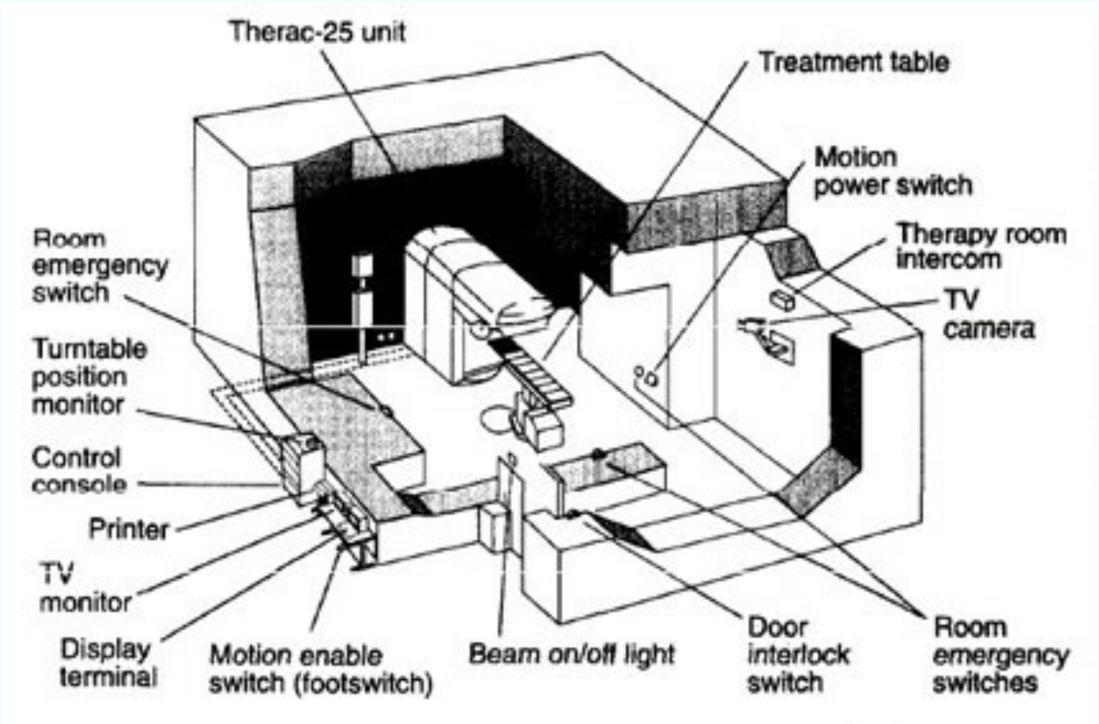
Implementation Error: Ariane 5 1996-6-04

Data conversion from 64-bit floating point to a 16-bit signed integer failed.

The ADA code software handler had been disabled. Cost $1Bn of your money.

A Chinook crash may have been caused by engine control sw bugs (1994)

System error: Therac 25 misuse



1985-7: 6 dead, others injured

Root cause: the 'guard' on the high-power beam was inadequate

SEC Phase 2: The Computation

- Thompson's Turing lecture 'Reflections on Trusting Trust' (1984)
  - "Nuances can be inserted at any level of the infrastructure"
  - … deliberately or accidentally
- Levels
  - 2.1: Hardware:
    - systematic, contingent and transient errors … chips, discs
  - Software:
    - 2.2: Microcode, kernel, operating system
    - 2.3: Compiler, collector, library routine
    - 2.4: Wrong input data … 'garbage in …'
- Consequent errors may be:
  - Systematic, contingent or transient

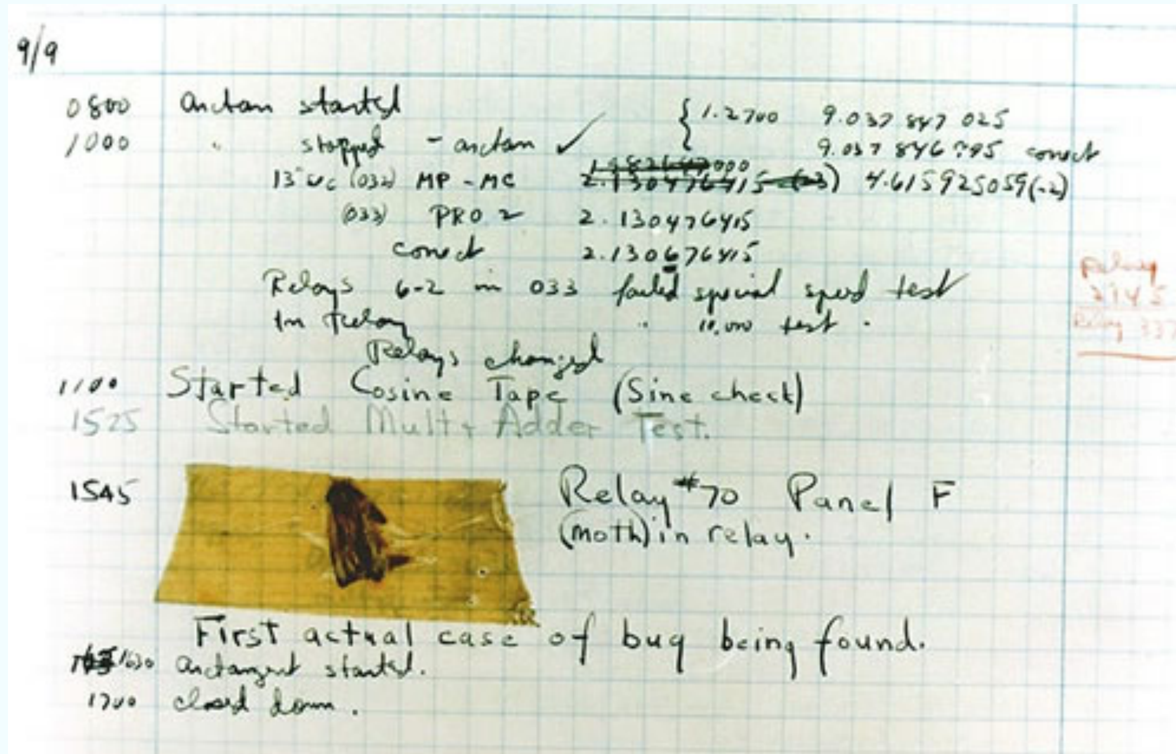
Systematic error: chip design

- Do we take chip integrity for granted?

- Pentium FDIV processor
- 1 in 9,000,000,000 operations wrong
- Some missing entries in a table

- Estimated cost $800m
- Intel now using HOL

Contingent error: Harvard Mark II



- The first computer bug … but not the first bug (Edison, 1878)

Transient Error: Radar Interference

- Field computer kept falling over quickly
- When we looked out of the window for inspiration, we saw …

SEC Phase 3: Use of the Output Data

3.1 Labelling or accessing the data incorrectly
3.2 Building on inadequate foundations
3.3 Shortcomings in the user's understanding
3.4 Physical data decay – file coatings are 'plastic' in nature
3.5 Constructing poor arguments based on probabilities

EGT-specific issues in SEC Phase 1

- **Ambitious modelling of subgames using chessic logic:**
  - **1.1a 1986: Komissarchik's KQPKQ EGT**
  - **1.1b 1987: Van Den Herik's KRP(a2)KbBP(a3) EGT**
- **1.1c Hiatus in DTM EGTs: mates in *m* but not in *m-1***
- **1.1d Forced capture by the loser: RETROENGINE, Wirth (1999)**
- **1.1e FEG:**
  - **The 'KNNK' bug: missing 'losses in 0'**
  - **The 'Transparent Pawn' bug**

EGT-specific issues in SEC Phase 2

- 2.1: Hardware errors, CPU, RAM, Disc [Schaeffer]
- 2.3a: Compiler errors: using 32-bit working in a 64-bit context [Schaeffer]
- 2.4a: Wrong input files:
  - 2-byte instead of 1-byte Nalimov format
  - the subgame's DTZ rather than DTZ50 EGT for a DTZ50 calculation
- 2.4b: Physical file decay
  - prevented only by using and checking signatures

EGT-specific issues in SEC Phase 3

- 3.1a: Mislabelling the output: Nalimov's mystery KBPKN stats file
- 3.1b: Using the wrong access routine: KINGSROW
- 3.1c: Using the wrong files:
  - DTC rather than DTM: watch the engine balk at actual capture!
  - Using DTZ rather than DTZ50 EGTs
  - 'Non peers' promulgated pornography under Nalimov filenames
- Thompson's EGTs
  - 3.2a Forgetting that KT's early KQPKQ EGTs ignored underpromotion
  - 3.2b Forgetting that they are White wins / does_not_win EGTs
    - Type 2 (010) zugs invisible; type 1 (121) and type 3 (020) indistinguishable
  - 3.3a Misinterpreting Thompson's depth-data
- 3.3c: Forgetting that EGTs do not include castling rights

The Declarative Approach

The Generic Approach and Benefits

Activity	Benefits
Set up the 'model world', i.e. the 'givens', within the logic	More powerful language English-like statements
Prove 'theorems' in the logic; logic engine verifies the proof	Combines human induction with silicon deduction
Outputs provably follow from inputs	Much lower risk that the outputs are not correct

HOL is the (Higher Order) Logic language referred to in this paper
However, the above is generic and applies to all logic languages.

HOL, Chess and EGTs

- **Note: SEC phases 1 and 2 conflate to a degree …**
  - **HOL is an Interactive Theorem Prover**
- **Phase 1**
  - **Model 'chess': FIDE Articles**
    - **Simplifications though: no Pawns, no castling rights**
  - **Model the Endgame Table**
    - **Using BDDs, first used by Gordon to provide solutions to Solitaire**
    - **Define 'the set of wins (losses) of depth *d*'**
  - **These are 'static aspects' of the model**

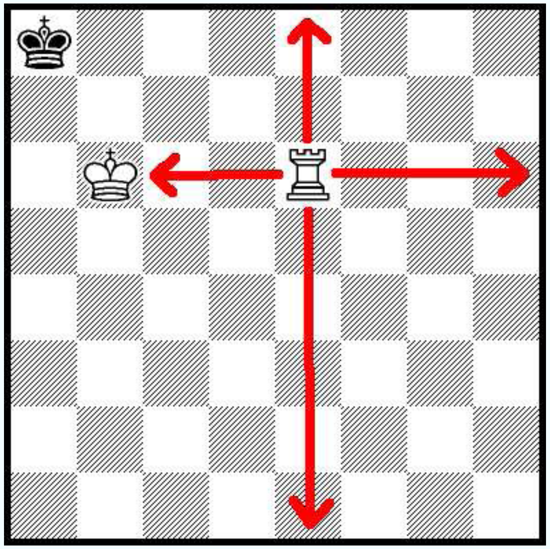
- **Phase1/2:**
  - **prove that the contents of the BDD follow from the definition of chess**

    as modelled from the FIDE Articles in HOL

HOL definition of Chess and EGTs

- Take a subset of the FIDE Articles of Chess, singly (or not):
  - those defining the Game but not those defining Rules of Play
  - not those defining pawn moves or castling
- Translate the text of the FIDE Articles into HOL
  - A task eased by the power and 'naturalness' of HOL
  - 'Higher Order' ⊃ ∀Sets $S \equiv \{m\}$ and ∀Functions $f{:}S_1 \rightarrow S_2$ as well as $\forall m$
  - this formalisation process might even reveal infelicities in the text
- Define EGTs in terms of Binary Decision Diagrams (BDDs)
  - Gordon first combined HOL and BDD re Peg Solitaire (2002)
  - Work back from checkmates, but 'symbolically' using BDDs
  - JH's work is the first demonstration of HOL/BDDs on 2-person games
- Result: not just text, but 'givens' (axioms) of the 'world' created
  - A starting-point for proving subsequent theorems (providing results)

The definition of the Rook Move



Articles 3.3 and 3.5 translated in combination …

3.3: line-piece

3.5: non-hopping piece

- **square** $\equiv \mathrm{N} \times \mathrm{N}$

  position $\equiv$ **side** $\times$ **(square** $\rightarrow$ **(side** $\times$ **piece) option)**
- **rook_attacks** *p a b*
- $a \neq b$ **^ (file** a **= file** $b \vee$ **rank** a **= rank** b**)**
- **^** $\forall c$**. square_between** *a c b* $\Rightarrow$ **empty** *p c*
- **The other rules of chess are similarly easy**

HOL Results

- 4-man pawnless Chess EGTs which have been proved …
  - to follow from the Laws of Chess
- Caveat at the logic level:
  - The 'environmental axioms' of this proof are that …
  - Everything the proof depends on is working properly
  - Hardware, the logic-engine and its runtime realisation
  - [… and this is where the JH-GH discussion started]
- Caveat at the physical level:
  - The price of this approach is more space and more time
  - we look to Moore's Law to ramp up memory and processor power

The Future

Emerging Opportunities and Challenges

- Parallel Computing
  - Has been 'in play' since 'Set Level Requests' were conceived
  - SQL is perhaps the most notable interface in this category
  - 'CPU' route is power-constrained: 'more' rather than 'faster'
  - Symmetric Multiprocessing is now 'on chip' on 'in-box' networks
  - This has created problems for both customers and suppliers
    - Customers have still not moved fully to a 'parallelised approach'
    - Customers are having to manage change in CPU/Memory balance
    - Suppliers are concerned that customers will not be able to do this
  - Supercomputing is an opportunity for the 'Declarative Approach'
- Community Computing
  - Using shared systems on the Web to energise various Diaspora
  - Enrich relationships within the Diaspora, mobilise activity, …

The Studies Community

- A (Win) Chess Study requires White to find the 'unique' winning line
- 'Unique' means 'essentially unique', not 'absolutely unique'
- But what alternative moves may be discarded?
- The FIDE PCCC has declared that 'cycling moves' may be ignored
  - these allow Black, defending, to force White to repeat a position
- The Study Community has long sought a tool to detect cycling moves
  - "the detection of blind alleys in general is notoriously difficult"
  - "detecting cycling moves can be … essentially impossible to do by hand"
- GH has now defined an algorithm, SEA, to detect cycling moves
  - Identifies the area of 'no return' to which White should not move
  - An implementation is in prospect … but what about Assurance?

Studies Community: Future Scenario

- There are some 70,000 studies in the corpus so far
- Members of the Studies Community apply SEA to a study
  - and report their findings on *cyclic moves* to the community
    - "given that positions p_1 to p_n have been visited, move m cycles"
    - these are non-trivial statements, easily mis-stated
  - The Mandler KNPKPP study of the Zugzwang paper would be 'target'
- Assurance issues, given the above framework:
  - Will the implementation of SEA be correct? Perhaps the least risk.
  - Will the users use the SEA tool correctly? Users are a big 'unknown'.
  - Will their results be correctly transmitted and understood?
  - Will their results be easier to verify than to find in the first place?
    - Does this 'desirable' increase the information that should be tabled?
- All these considerations have an effect on 'SEA' implementation

Summary

- The creation of EGTs is a complex and little understood task
- The EGTs now 'front' the domain of sub-7-man Chess
- They must therefore be correct but this is not certain in the future

- Themes from this review:
  - Collect data on errors as the foundation for Assurance Discussions
  - No magic solutions but a framework of generic remedies
  - At root, the precise meaning of the objects of the computation … and the context in which they are used … must be defined

- The future: Community, and Parallel, Computing
  - Provides opportunities for enriching the social fabric
  - Provides opportunities for greater use of the declarative approach