Actors

The Past and Future of Software Engineering

Juval Löwy
www.idesign.net

About Juval Löwy

- Software architect
  - Specializes in architecture and project design
  - Helped hundreds of companies meet their commitments
  - Conducts Master Classes the world over
- Recent book
  - Righting Software (2019, Addison-Wesley)
- Published more than 100 articles
- Speaks at major international development conferences
- Participated in Microsoft's strategic design reviews
- Recognized Software Legend by Microsoft
- Contact at www.idesign.net

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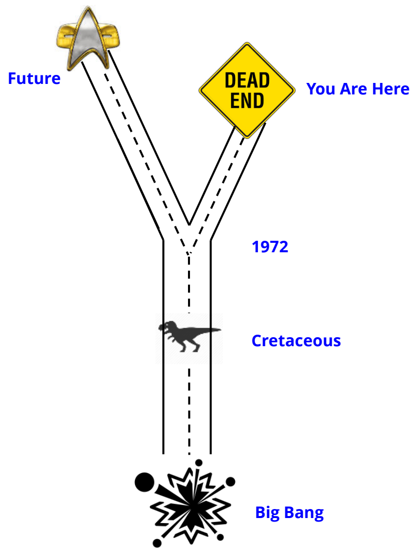
Brief History of Time



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The Road Taken

- In the early 70's computers were
  - Expensive to purchase
  - Expensive to operate and own
  - Large
  - Complex hardware monolith
    - Not modular
  - Shared across many users
    - Strong driver to share as much as possible
    - Not personal
    - Time sharing limitation

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The Road Taken

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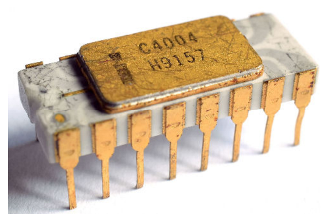
The Road Taken

- All that has changed with Intel in 1971
  - First commercial micro chip
  - 4 bits 4004 chip
  - Followed by 8008
- Real breakthrough was 8080 in 1974
  - The first Altair PC
- Moore's Law takes off



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Moore's Law

- Number of transistors per chip doubles every two years
  - Coined in 1975 a year after the 8080
- Performance actually doubled every 18 months
  - Not just more but faster transistors

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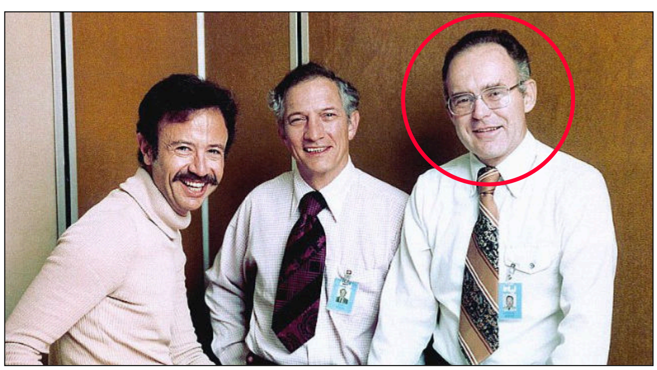
Moore's Law

- Moore's Law lifted the industry for 40 years



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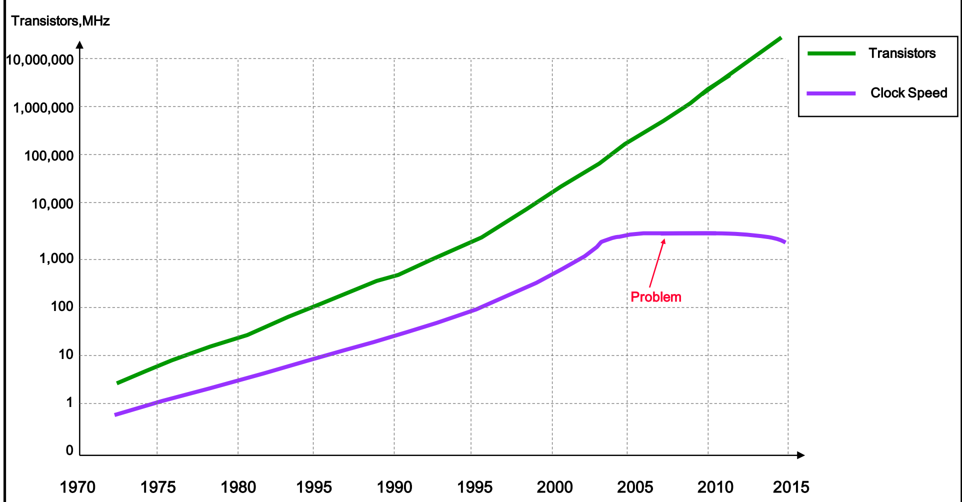
Moore's Law



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Moore's Law Demise

- Cannot make silicon gates any smaller
  - At affordable price
- Manufacturing issues
  - Well under light wave length
  - Material purity
  - Quality control
  - Quantum effects
  - R&D costs

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Moore's Law Demise

- Rock's Law for semiconductor manufacturing
  - Fabrication plant cost doubles every four years
- In a finite world all exponential growth must come to an end
  - At some point
  - 2012 was as good point as any

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Moore's Law Demise

- Virtuous circle stopped
  - HW→SW→HW→SW→ ....
- Microsoft responded by leaving the desktop and moving to the cloud
- Intel responded by doing more of the same

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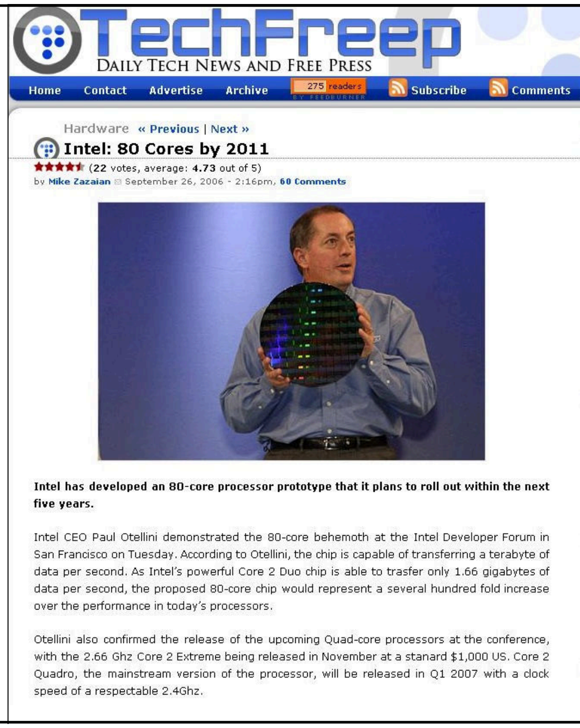

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Hardware « Previous | Next »

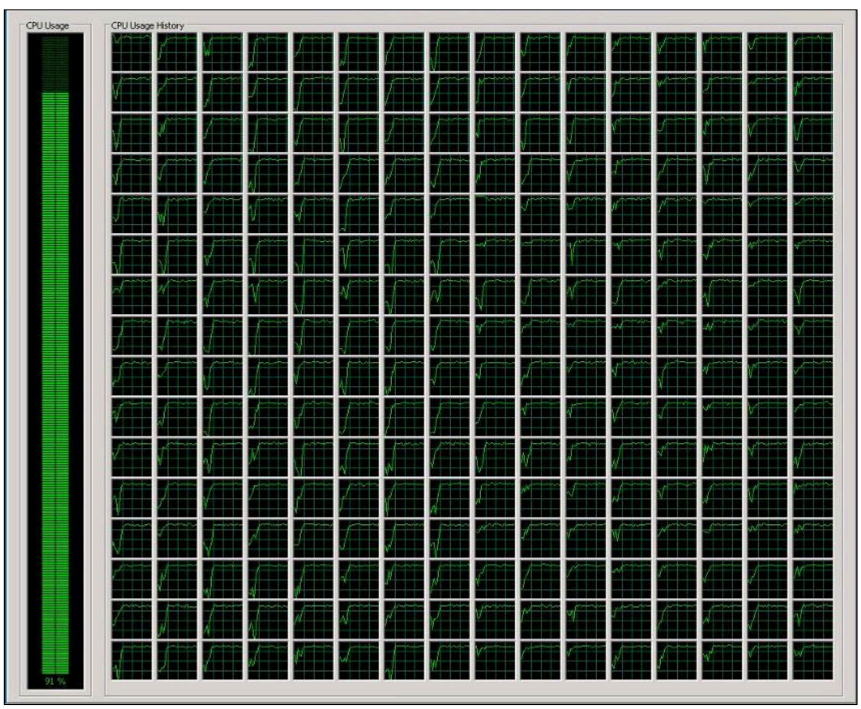
Intel: 80 Cores by 2011

(22 votes, average: 4.73 out of 5)
by Mike Zazaian @ September 26, 2006 - 2:16pm, 60 Comments

Intel has developed an 80-core processor prototype that it plans to roll out within the next five years.

Intel CEO Paul Otellini demonstrated the 80-core behemoth at the Intel Developer Forum in San Francisco on Tuesday. According to Otellini, the chip is capable of transferring a terabyte of data per second. As Intel's powerful Core 2 Duo chip is able to trasfer only 1.66 gigabytes of data per second, the proposed 80-core chip would represent a several hundred fold increase over the performance in today's processors.

Otellini also confirmed the release of the upcoming Quad-core processors at the conference, with the 2.66 Ghz Core 2 Extreme being released in November at a stanard $1,000 US. Core 2 Quadro, the mainstream version of the processor, will be released in Q1 2007 with a clock speed of a respectable 2.4Ghz.



Moore's Law Demise

- Developers cannot take advantage of multiple cores
- Hyper core increases
  - Synchronization issues
  - Misalignment with real world and business processes

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Latent Consequences of The Road

- Information was arranged sequentially
  - Punch cards or tapes
  - Made program itself sequential
- Most of the computer is idle most of the time
  - Memory not used
  - I/O is the bottleneck
  - Nothing ever happens in human time scale
- Requires threads and locks
  - Does not scale
  - Very complex
  - Out of reach for most

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Where We Are Today

- No single computer can scale up with sufficiently large and complex business process
- Inherit mismatch between parallel business processes and single central processing unit
  - Software cannot mimic reality well
  - Business conforms to software
- Requires distributed computing
  - Really difficult
- Industry has very poor track record
  - Programmers out of their depth
  - Never trained or qualified

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Where We Are Today

- Sequential programs against central processing unit has established itself as the way to program
  - THE only way to program
- Why what comes next looks initially totally alien
  - But is in fact much simpler

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The Road Not Taken

- In the early days there was another way
  - The C in **C**PU was there for a reason
- Many cheap simple computers
  - Instead of one large expensive computer
  - Mesh computing as early as 1968
    - Network of processing units
    - No single central processing unit

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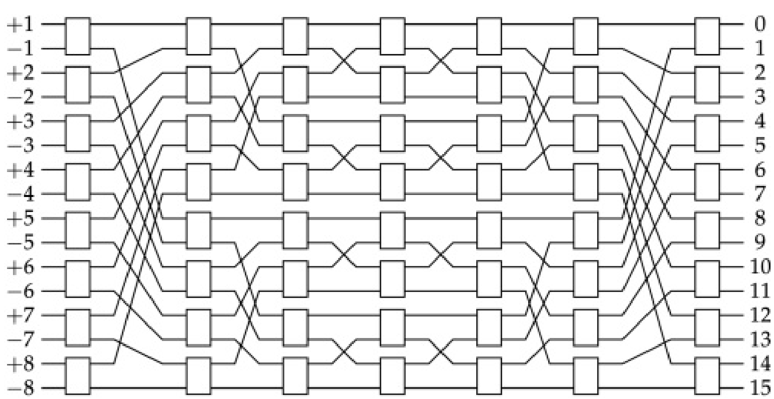
The Road Not Taken

- Required dedicated hardware designed for task



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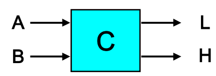
Sorting Network

- Example
  - Sorting networks
  - Can sort n numbers in 1 tick
- A comparator unit
  - Receives two inputs A and B
  - After "tick" or message, places the lower value on output L and the higher on H



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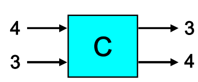
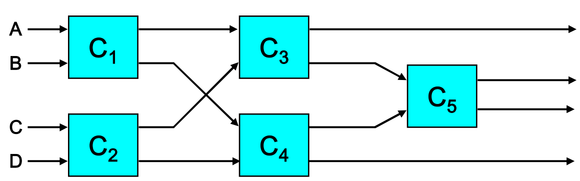
Sorting Network

- Comparator in one steps sorts two values



- Can use as building blocks of 4 values sorting unit in 3 steps



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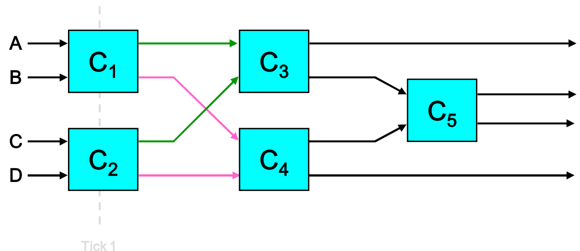
Sorting Network

- After Tick 1
  - C_3 is fed the lowest two values out of the four
  - C_4 is fed the highest two values out of the four



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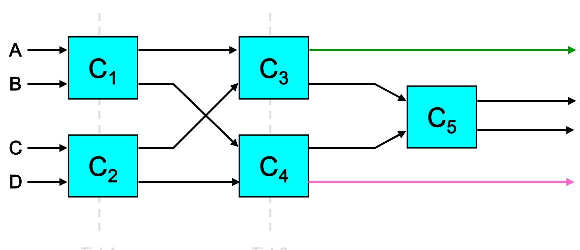
Sorting Network

- After Tick 2
  - The lower value of C_3 is the lowest of the four
  - The higher value of C_4 is the highest of the four



  - Those can just be put out
  - All that is left is to sort the middle two values

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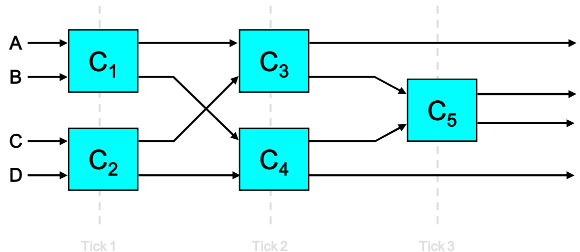
Sorting Network

- After Tick 3
  - C_5 sorts the middle two values
  - All four values are sorted out



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Sorting Network

- Sequential programming can only sort O(n log n)
  - Cannot process on-going feed without buffering
- Sorting network can do O(1) for continuous feed of values
  - After filling the pipes
- Use sorting network of n to build n+1 and 2*n network
  - Several optimized solutions exists

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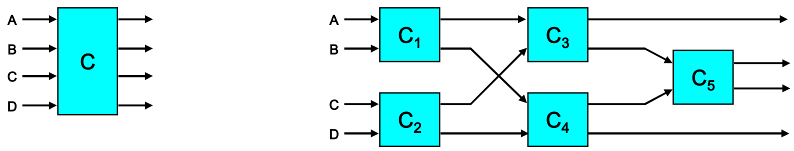
Sorting Network

- View as single new unit for sorting 4 values



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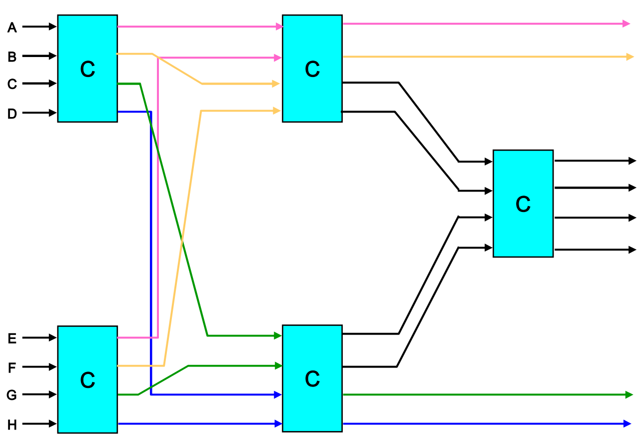
Sorting Network

- Can use that to sort 8 values



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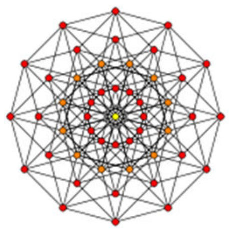
The Road Not Taken

- Other much more sophisticated algorithms rely on three dimensional layout of processing units or hyper cubes
- Often arranged in fractal hierarchies
  - Can be generic or domain-specific topology
- Network can be fixed, change with the business or at runtime



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The Road Not Taken

- Scales much better
- Utilized hardware most of the time
- Massively parallel hardware never came
  - Intel was too successful and Moore's Law too compelling

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The Road Not Taken

- Today we can use software to emulate the missing hardware
  - One thing we do not miss is horsepower
  - The cloud provides unparallel processing power
    - Pun intended
- The actor model is one such option

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The Actor Model

- Actors model in 1973
  - A year before the 8080
- Today the only way to build the Greater IoT
  - Handle the scale and concurrency
  - Volume
    - Number of devices
    - Rate of data change
  - IoT added value is with dynamic data
- Correct modeling of the real world and business processes

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The Actor Model

- Each actor emulates a simple processing unit
- Instead of dedicated hardware wiring use messages and addresses
- All actors execute concurrently to all other actors
- Actors can manage internal state
  - Ideally very limited and simple
- Actors can never directly change other actors state
  - No need to synchronize yet benefit from massive concurrent parallel execution
- No sequential computation

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The Actor Model

- Actors often arranged into hierarchy of networks
  - All actors at the same level are identical
  - Across levels actors are different
- Strive for dumb actors and smart networks
  - Each actor performs very simple, repetitive task
  - Like movie set or factory floor
- Actual program is the layout of the network
  - Not the code in the actors
- To change the program change the network
  - Hardly ever change individual actors

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Actor Model Examples

- Example - typical company or organization
- Companies cannot rely on superheroes
  - Does not scale anyway
  - Use multiple regular people instead
- Each employee is an actor
- The lowest level workers perform repetitive simple tasks
- Company is organized into hierarchy of networks of actors
  - Individual
  - Team
  - Division
  - Company

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Actor Model Examples

- To change how the company operates perform "re-org"
  - Company reprograms itself
  - Changes report structure and wiring
  - Actual actor work hardly ever changes
- Managers are also actors managing lower actors
- Information flows through the company in the form of messages
  - Email, mail, voice mail, memos, yammer, CRM
- Ideally no actor should block any other actors
  - Actual efficiency will vary

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Actor Model Examples

- Example - LED matrix
- Each LED is simple actor that can turn ON or OFF
  - Each LED forms a simple network of one actor
- LED actors are arranged in simple grid to form a character
  - The character network
- Each character is an actor that knows how to convert ASCII to ON/OFF messages for its LED actors
  - All LED actors change state concurrently
- Character actors are arranged in sequence to form a row
  - The row network

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Actor Model Examples

- Each row is an actor that knows how to convert a string to individual character messages for its message actors
  - All character actors change state concurrently
- Row actors are arranged in simple sequence to form a page
  - The page network
- Each page is an actor that knows how to convert a multiline string to individual string messages for its row actors
  - All row actors change state concurrently
- Pages are arranged into a book
- Books into library
- ...

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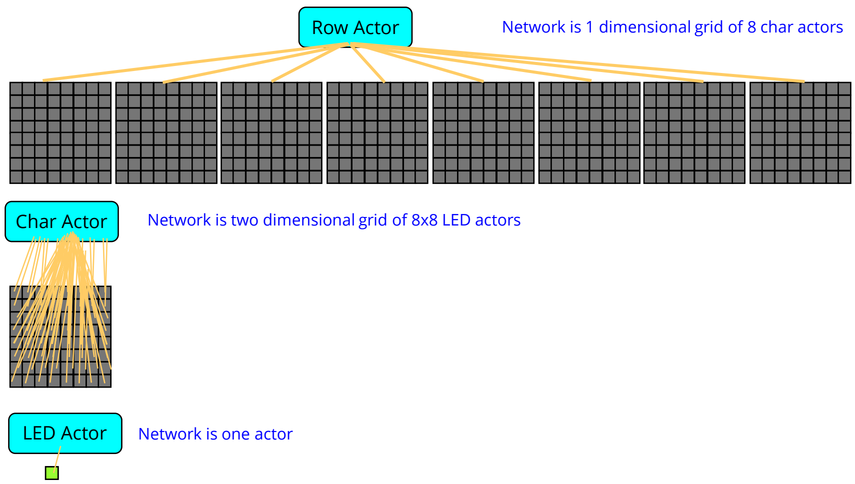
Actor Model Examples



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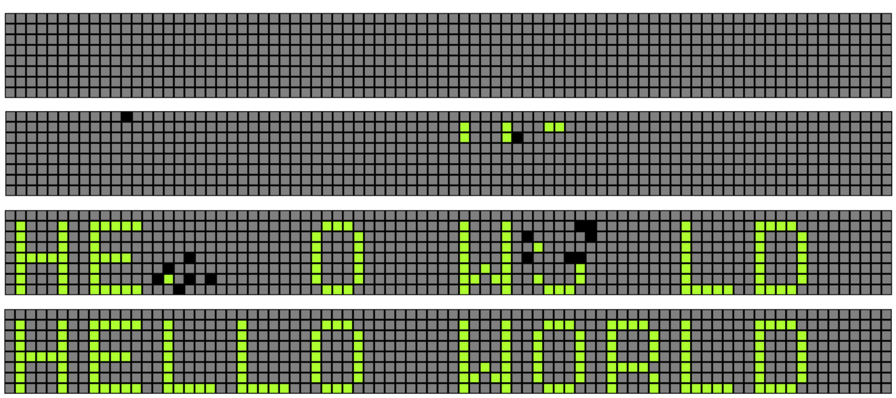
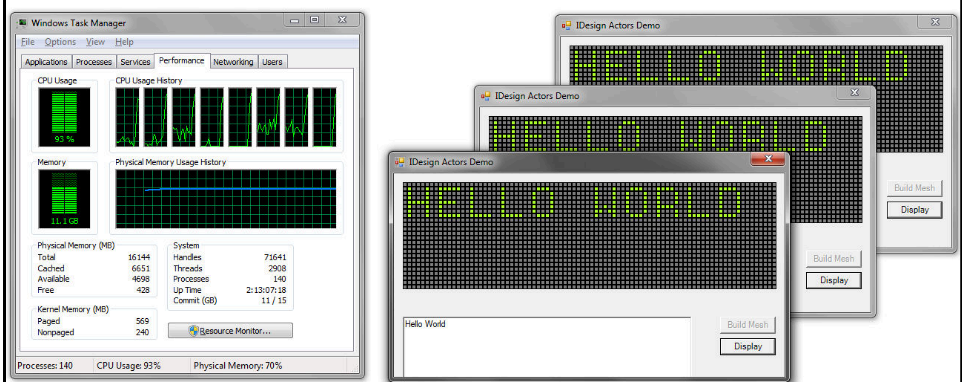
Actor Model Examples



Actor Model Examples

- Why you need dedicated platforms for actors



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Actor Model Examples

- Example - car assembly line
- Each worker is an actor performing simple repetitive task
- Each stop is concurrent to all other stops
- All the smarts is in the design of the assembly line
- Partly-built car and parts arriving and leaving each stop
  - Actor state and I/O messages
- Key observation
  - It is the progression of the car through the line that is the assembly of the car
  - It is the progression of the messages though the network that is the execution of the program

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Actor Model Examples

- Observations
  - Small simple steps comprise complex objective
  - Very difficult to do using traditional programming
  - Can change factory without disturbing actors
- Now extend to entire factory supply chain
  - From part makers to trucks to dealers
- Now extend from customers to financing

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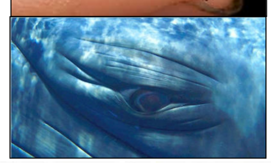
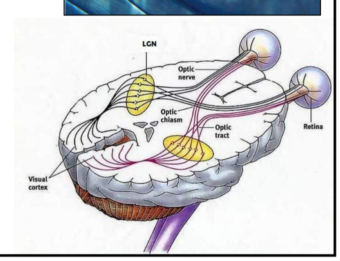
Actor Model Examples

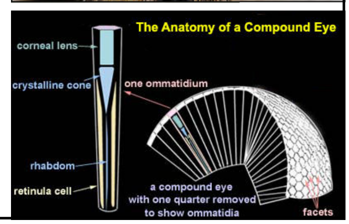
- Vertebrates vision is like sequential CPU
- System design attributes
  - Eyes with wide field of view
  - High resolution
  - Dynamic focal plane
    - Pin pointing object in space one at a time
    - Moving eyes
  - Large and expensive system
    - Eyes, nerves, brain
    - Requiring huge bandwidth
  - Processing one image at a time
- Fragile with little redundancy





Actor Model Examples

- Insects vision use thousands of eyes in 3D actors mesh
- System design attributes
  - Eyes with narrow field of view
  - Low resolution
  - Static focal plane
    - Tracking all objects concurrently
    - Static eyes
  - Numerous and cheap eyes
  - No brain required for processing
    - No concept of single image
- Simultaneous unmatched detection of multiple moving objects in space



Actor Model Examples

- For centuries telescopes mimicked the human eye
  - Large
  - Complex
  - Expensive
  - Time-sharing
- Does not have to
  - Already better at detecting extremely remote dim objects

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Actor Model Examples

- Next generation command and control systems


Defense One
NEWS THREATS POLITICS BUSINESS TECH IDE

The Future the US Military is Constructing: a Giant, Armed Nervous System

BY PATRICK TUCKER
TECHNOLOGY EDITOR
READ BIO

SEPTEMBER 26, 2017

TOPICS
TECHNOLOGY

Service chiefs are converging on a single strategy for military dominance: connect everything to everything.

Leaders of the Air Force, Navy, Army and Marines are converging on a vision of the future military: connecting every asset on the global battlefield.

That means everything from F-35 jets overhead to the destroyers on the sea to the armor of the tanks crawling over the land to the multiplying devices in every troops' pockets. Every weapon,

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Actor Model Examples

- OK, they are building Skynet

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Market Drivers

- Business software got too complex
  - Unmaintainable monoliths
  - Resource crisis
- High affinity modeling of the real world
  - Easier too

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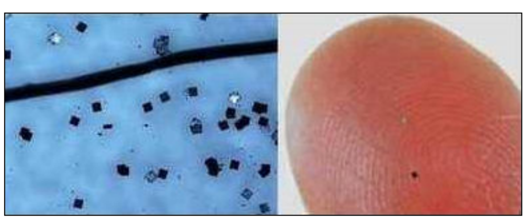
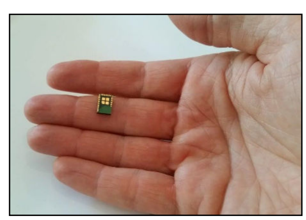
Market Drivers

- The Greater IoT
  - Trillion of connected devices
- $7 computers on a chip
  - Smart dust is next
- Every "thing" should be an actor
  - Juval Lowy in 2009 envisioning the IoT





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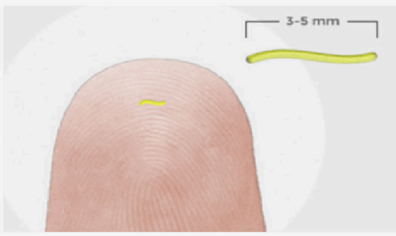
Market Drivers

- Body implants

DIGITAL TRENDS Product Reviews + New

EMERGING TECH

DARPA invests $7.5 million into Profusa's tiny tech-packed implantable biosensor



The Defense Advanced Research Projects Agency announced a project with the U.S. Army Research Office to develop tissue-integrated biosensor technology. Profusa, a San Francisco company, was awarded a $7.5 million grant from DARPA to lead the development.

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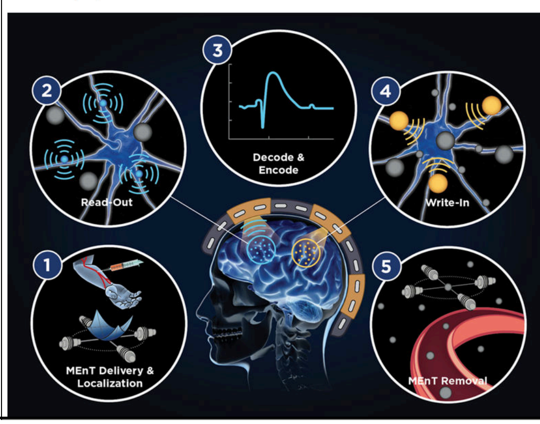
Market Drivers

Battelle-Led Team Wins DARPA Award to Develop Injectable, Bi-Directional Brain Computer Interface

Posted on May 20, 2019



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What Are Actors

- Actors are services
  - Very simple services
  - Services already use messages not thread call stacks
  - Services already are addressable
- Actors make sense en-masse
  - There is no utilization for "an actor"
- Actors are small
  - Networks are large
- Actors are always arranged in a network or mesh

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Addresses

- Addresses can be unique
- Actors can share an address
- An actor can monitor multiple addresses
- Design so you never need to know identity of actors behind addresses
  - Like employees of a company servicing your request
- Actors can act as proxies to other actors
  - For security reasons
- Message can contain address of other actors
  - Dynamic networks

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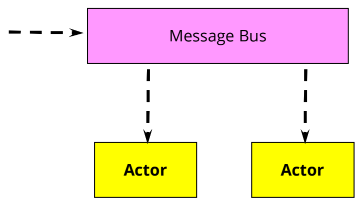
Broadcast

- Since multiple actors may monitor same address can use that for broadcasting messages
  - When two or more subsystems need to respond to message
- Typically use a message bus



- Can even have hierarchy of subsystems and buses

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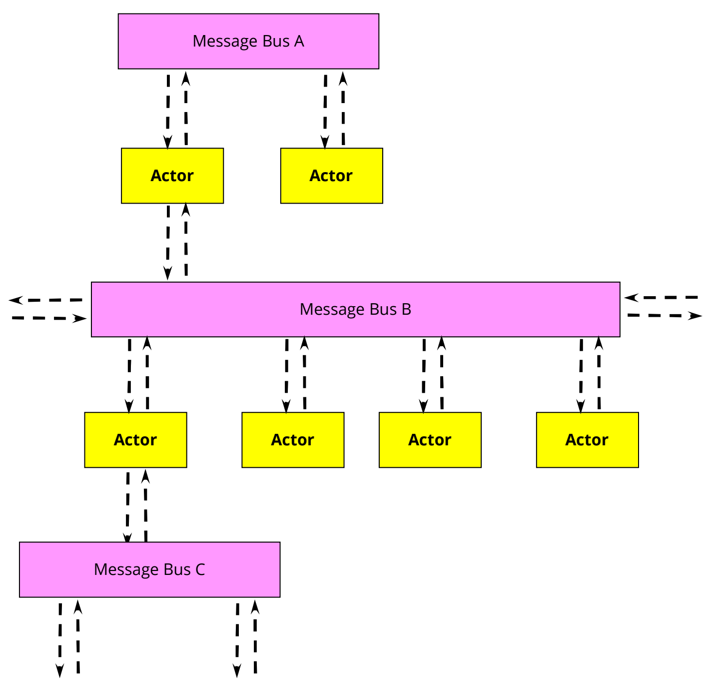

More on Actors

- Actors shine with processing pipelines
- Strive for modular design of actors
  - Can add more of the same
  - Larger house is made of more bricks not larger bricks
  - Can use as building blocks of higher abstraction

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More on Actors

- Again
  - Strive for dumb actors and smart network
  - To change the program change the network

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More on Actors

- Dumb is from the business perspective
  - LED does not know there is a message
- Dumb means
  - Very simple externally accessible behavior
    - Single facet with a very few operations (1-2)
  - Follows closed architecture
    - Only aware of system aspects one layer below
    - Never above
  - Always in smart hierarchy
  - Business value via composability of the network

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Conclusion

- Actors are an alternative way of programming
- Looks initially totally alien
  - But is in fact much simpler
- Contrast that with prior "alien" ideas
  - Microservices

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More at DevIntersection

- Composable Design
  - Tuesday 12:00 PM

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Resources

Juval Löwy
www.idesign.net

Resources

- Slides
  - www.idesign.net/DevInt

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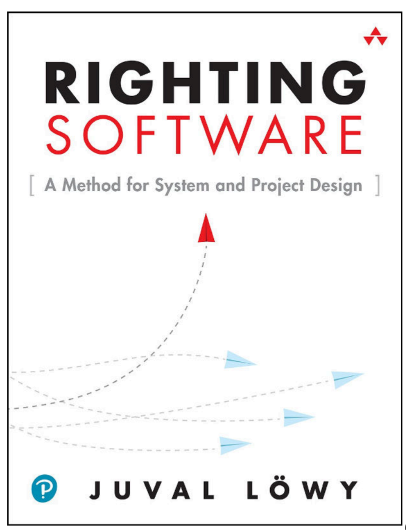
Righting Software

- Addison-Wesley
  - December 2019
- www.rightingsoftware.org



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