Heterogeneous Modeling and Design

UC Berkeley Project - UT Austin Subcontract

hmad98ucb.fm

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Replace Custom Sonar Front-end with a Single Workstation

- Software sonar front-end merges three technologies:
  - symmetric multiprocessing on Unix workstations
  - lightweight POSIX threads (AIX, Irix, HP-UX, Linux, Solaris)
  - Process Network model (concurrency, determinism, boundedness)
- Real-time 4-GFLOP digital interpolation sonar front-end using 16 x 300 MHz UltraSPARC-IIs: cascade of 1 vertical beamformer (80 staves, 10 sensors/stave, 100 kHz, 16 bits, 160 MB/s, 3.5 CPUs), 3 horizontal beamformers (*each*: 80 staves, 61 beams, 32-bit floats, 32 MB/s, 4 CPUs), and 3 shifters/decimators
- Workstation reduces weight, volume, development time by factor of two, and

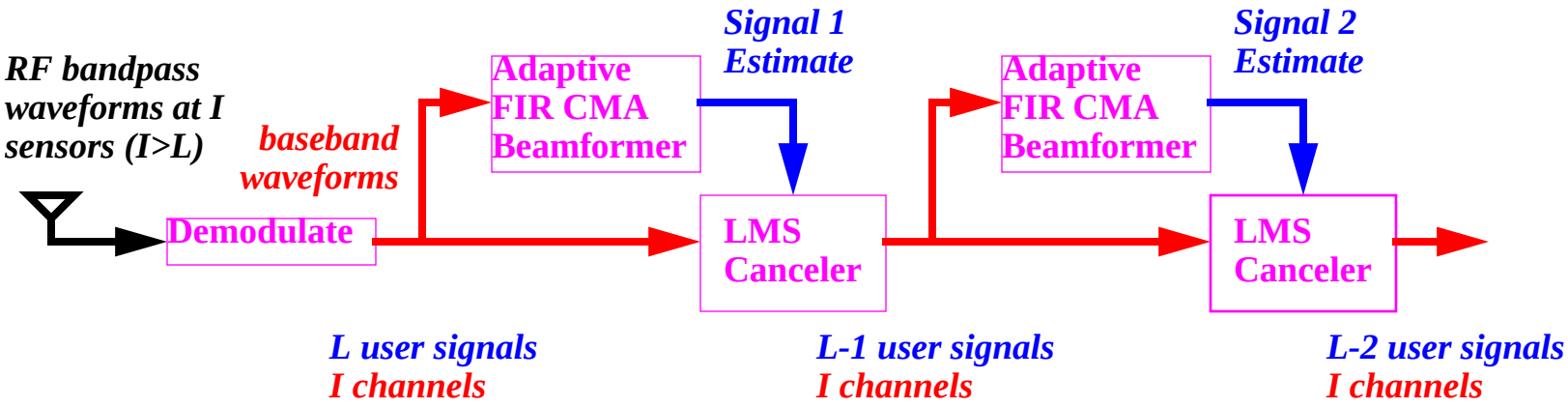
Sonar Front-end	Sonar Manufacturing Cost	Sonar Development Cost
Custom Hardware	$1,000,000	$3,000,000
Ultra-2 6000 Server	$400,000	$300,000

- CAD tools can be deployed with the workstation
- Tutorial on Process Networks, beamforming, and Process Network sonar:

http://www.ece.utexas.edu/~allen/GuestLecture.html

Digital Subsystem for a Mixed RF/Analog/Digital System

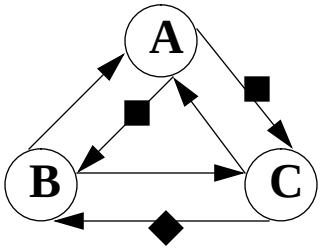
- Constant Modulus Algorithm (CMA) for blind channel equalization
  - Use *I* sensors to track *L* users sending CM signals (QPSK, FSK) where *I* > *L*
  - Receive narrowband (IS-95, GSM) waveforms from users in the far-field
  - Channel model includes Rayleigh fading; SNR > 10 dB at receiver output



- Embedded real-time implementation in software on a digital signal processor:
  - 2 *I L* adaptive FIR filters + *L* CMA decisions: $O(L^3)$ multiply/adds
  - Acyclic Homogeneous Synchronous Dataflow (SDF) specifies CMA algorithm
- We make CMA insensitive to channel phase shifts by modifying decision process
- New Ptolemy 0.7.1 simulations (Synchronous Dataflow) and generated C code

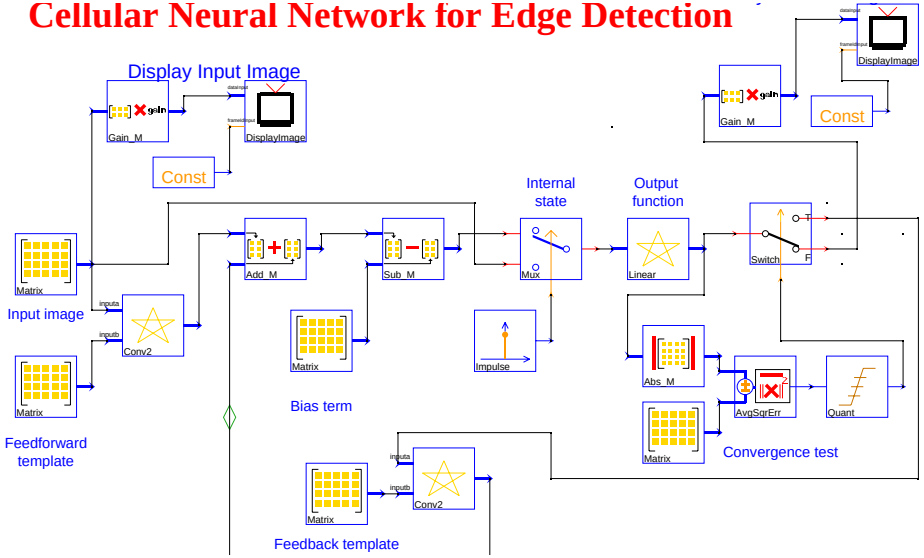
Heterogeneous Design Styles & Implementation Technologies

- Use dataflow models to specify hybrid Artificial Neural Network (ANN) and Digital Signal Processing (DSP) systems for simulation and synthesis
  - ANNs during training: Boolean dataflow (BDF)
  - ANNs during classification: Homogeneous Synchronous Dataflow (HSDF), except Cellular Neural Networks require BDF models (w/ static schedules)
- Examples of hybrid ANN and DSP systems
  - Mixture: Gamma Memory Model (add FIR filters on inputs of neurons)
  - ANN followed by DSP: Cellular Neural Network detects impulsive noise in images which is removed by a median filter
- ANN Ptolemy demos under SDF ... Contributions



HSDF Hopfield ANN

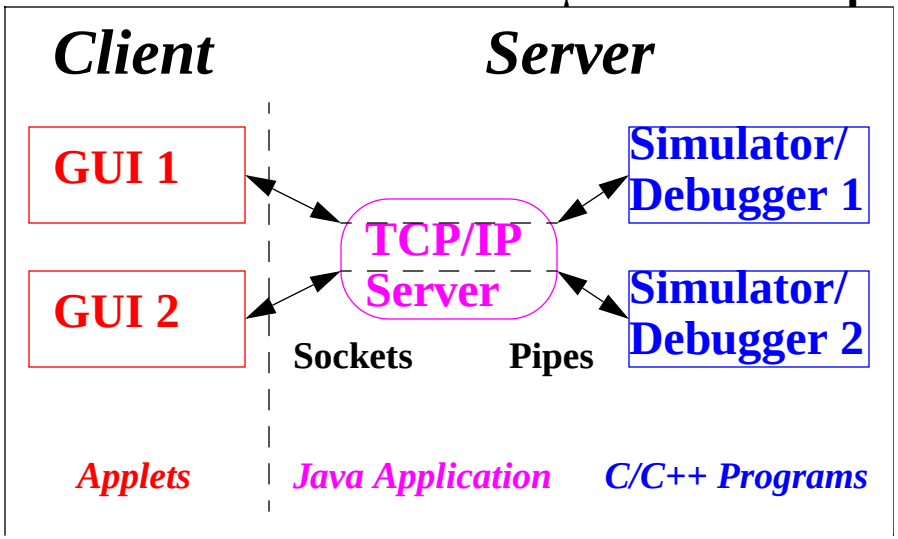
Cellular Neural Network for Edge Detection



Web-Enabled Simulation of Embedded Software

Evaluate, Benchmark, Develop Embedded Applications

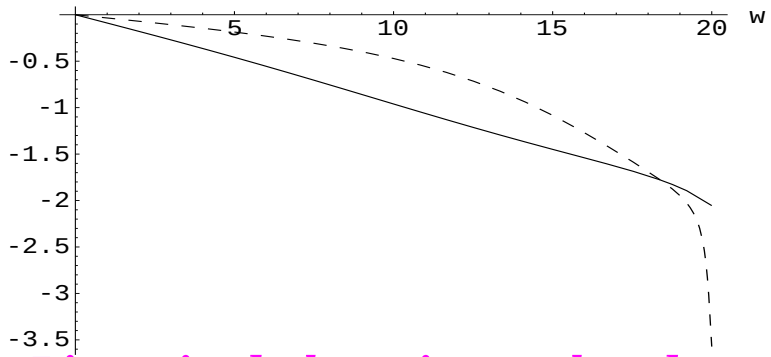
- Immediate access to latest DSP/microcontroller simulation & board technology
- Simulator applet: generic interface to server for use by other Web CAD tools
- Modern replacement for TechOnLine's telnet interface to DSP boards
  - *portable* - GUI, server, simulators/debuggers work under Unix & Windows
  - *configurable* - GUI customizes appearance based on feedback from tool
  - *extensible* - add command-line simulator/debugger without changing code
- Tools: C30 DSP & HC11 µC simulator plus MC56800 DSP simulator & board



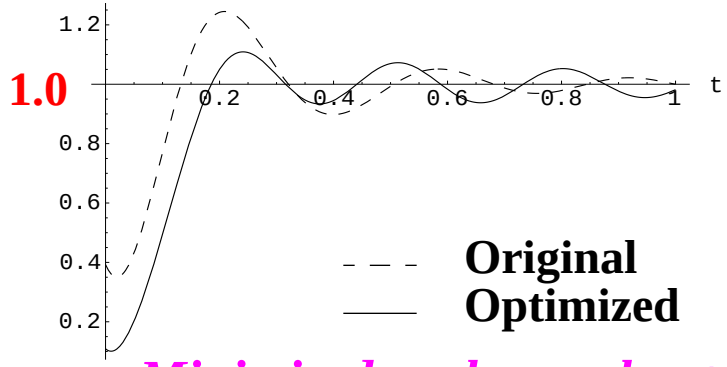
http://anchovy.ece.utexas.edu/~arifler/wetics

Automated Multi-Criteria Optimization of Filter Designs

- Optimize behavioral and implementation characteristics
  - Constrained non-linear optimization as Sequential Quadratic Programming: converges to global optimum & robust when closed-form gradients provided.
  - Program Mathematica to derive formulas for cost function, constraints, and gradients, and convert the formulas to Matlab programs to run optimization.
- Example: Linearize phase and minimize overshoot of an analog elliptic filter design subject to constraints on magnitude, overshoot, and quality factors (Q)



Linearized phase in passband



Minimized peak overshoot

  - Constraining Q_{max} to 10 reduced Q_{max} from 61 to 10: filter now realizable
- Filter Optimization Packages available for download:

http://www.ece.utexas.edu/~bevans/projects/syn_filter_software.html

Summary - UT Austin Subcontract, Prof. Brian L. Evans

Deliverables

- G. E. Allen, D. C. Schanbacher, and B. L. Evans, "Real-Time Sonar Beamforming on a Unix workstation Using Process Networks and POSIX Threads", Invited, *Proc. IEEE Asilomar Conf. on Signals, Systems, and Computers*, Nov. 1-4, 1998.
- S. Gummadi and B. L. Evans, "Cochannel Signal Separation in Fading Channels Using a Modified Constant Modulus Array". Invited, *Ibid*.
- A. Kulkarni, A. Dube, and B. L. Evans, "Benchmarking Code Generation Methodologies for Programmable Digital Signal Processors". Invited, *Ibid*.
- N. Damera-Venkata, B. L. Evans, M. D. Lutovac, and D. V. Tosic, "Joint Optimization of Multiple Behavioral and Implementation Properties of Analog Filter Designs", *Proc. IEEE Int. Sym. on Circuits and Systems*, May 1998.
- B. Lu, B. L. Evans, and D. V. Tosic, "Simulation and Synthesis of Artificial Neural Networks Using Dataflow Models in Ptolemy", Invited, *Proc. IEEE Conf. on Neural Network Applications in Eng.*, Sep. 8-9, 1997, pp. 84-89.
- D. Arifler, C. Duong, B. L. Evans, and S. Gummadi, "Web-Enabled Texas Instruments TMS320C30 Simulator," TI DSP Solutions Contest, Nov. 1997.
- Software: N. Damera-Venkata and B. L. Evans, "Filter Optimization Packages".
- Software: B. L. Evans, *et al.*, "Web-Enabled Simulation".
- On-line Courses: *Embedded Software Systems* and *Real-Time DSP Laboratory*

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