From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, February 5, 2017 5:55 PM
To: Paul Allen
Subject: Atlanta

Well, the Hawks lost to a really good team!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Wednesday, March 29, 2017 3:10 PM
To: Paul Gilbert;Paul Allen
Subject: Bill Gates and Paul Allen had a business before Microsoft, and this engineer was their partner - GeekWire

http://www.geekwire.com/2017/bill-gates-paul-allen-business-microsoft-engineer-partner/?utm_source=GeekWire+Newsletters&utm_campaign=f6815b81c4-GeekWire_Deals_Weekly&utm_medium=email&utm_term=0_4e93fc7dfd-f6815b81c4-230191465&mc_cid=f6815b81c4&mc_eid=a3979936b5

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Wednesday, April 26, 2017 2:23 PM
To: Paul Allen
Subject: WOW!!!

This is PHENOMENAL!!!

http://www.seattletimes.com/seattle-news/billionaire-paul-allen-pledges-30m-toward-permanent-housing-for-seattles-homeless/

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Monday, November 7, 2016 5:53 PM
To: Paul Allen
Cc: Bert Kolde;Allen Israel;DaveS@vulcan.com
Subject: WOW!

I am completely speechless:

Incredibly grateful for your amazing generosity.

Hugely proud that we will forever be associated with your name.

Totally committed to ensuring that you, in turn, are proud to have your name associated with us, and feel that we are fulfilling your expectations.

THANK YOU!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, January 12, 2017 3:28 PM

To: paul@vulcan.com

Subject: UW Regents approve CSE2 construction!

A quick news update: Minutes ago, the UW Board of Regents formally approved the start of construction on CSE2. There will be preliminary action on the jobsite next week (fencing, trailers, etc.) and serious action (or, as we say, "concrete indications of progress") the week after that.

So, we're on the way!

From: Paul Allen <Paul@vulcan.com>
Sent: Sunday, January 22, 2017 1:04 PM
To: lazowska@cs.washington.edu
Subject: RE: Happy ...

Thanks Ed! Weird to have a birthday that is 2 ^ 6! Paul

-----Original Message-----
From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Saturday, January 21, 2017 3:01 PM
To: Paul Allen <Paul@vulcan.com>
Subject: Re: Happy ...

(Actually, upon reflection, I'm 2 scary years older than you - demonstrated by my miscalculation. But happy birthday regardless!)

On Sat, Jan 21, 2017 at 8:43 AM, Ed Lazowska <lazowska@cs.washington.edu> wrote:
> birthday. (We are the same scary age.)

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, April 13, 2017 1:24 PM
To: Paul Allen
Subject: Kildall's book

Paul,

Last night was phenomenal! Thanks so much for including me and Lyndsay.

I have two of the 20 copies of Gary Kildall's unpublished book. I'll send one down to you at Vulcan. Gary's is an incredibly sad story: many contributions, many successes, but drank himself to death lamenting what might have been and blaming others. (I think you'll agree, once you've read the book, that we're all fortunate it was not published ...)

Here's a web page from the dedication of the IEEE plaque. There's a photo of the bottom of Tom Rolander with Gary's son and daughter. We have a duplicate of the plaque in CSE - I asked IEEE to make one for us.

https://news.cs.washington.edu/2014/04/26/photos-of-the-ceremony-ieee-milestone-plaque-honoring-uw-cse-ph-d-alum-gary-kildall/

Gary's daughter Kristin lives in Seattle. His son Scott is a SF digital artist - there's some pretty cool stuff on his web page:

http://kildall.com/

I mentioned that Tim Paterson was a UW CSE bachelors alum. We gave him our annual Alumni Achievement Award at our graduation ceremony few years ago:

https://news.cs.washington.edu/2015/06/12/tim-paterson-kevin-jeffay-receive-2015-uw-cse-alumni-achievement-awards/

Book will follow shortly. Thanks again!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Saturday, January 21, 2017 8:44 AM

To: Paul Allen

Subject: Happy ...

birthday. (We are the same scary age.)

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, March 9, 2017 2:10 PM
To: Paul Allen;Steve Lombardi
Subject: Done!

2:09 p.m. and we are REAL!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, March 10, 2017 9:11 AM
To: Kristin Osborne;Steve Lombardi;Paul Allen
Subject: GeekWire interview with Paul just posted

http://www.geekwire.com/2017/conversation-microsoft-co-founder-paul-allen-really-golden-age-whats-possible/

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, March 24, 2017 6:17 AM
To: Paul Allen;Bert Kolde;Allen Israel;Oren Etzioni;Dave Stewart
Subject: Nice article in a philanthropy magazine

https://www.insidephilanthropy.com/home/2017/3/21/paul-allen-philanthropy-uw

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, February 26, 2017 7:05 AM
To: Paul Allen
Subject: Traf-O-Data

Paul,

I heard that you might bring the Traf-O-Data computer on March 9. Super!

This has been one of my all-time favorite articles:

http://www.newsweek.com/my-favorite-mistake-paul-allen-66489

We are planning an interactive display for the CSE2 building (and probably re-fit to the Allen Center as well) that seeks to inspire future generations of students to "think big" by illustrating the amazing things that have happened in Seattle tech in the past 50 years, and the fits-and-starts along the way. The story told in the article is *precisely* the sort of material we want to include - it's a bullseye.

(I've had some preliminary conversations with Lath Carlson about the interactive display idea; he has kindly offered to help.)

See you soon!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, March 9, 2017 11:01 AM
To: Paul Allen
Subject: So far so good!

No surprise: huge enthusiastic grateful thumbs-up at the committee meeting just now. Full board in early afternoon is a rubber stamp. You'll need a speech this afternoon!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Saturday, January 21, 2017 2:01 PM
To: Paul Allen
Subject: Re: Happy ...

(Actually, upon reflection, I'm 2 scary years older than you - demonstrated by my miscalculation. But happy birthday regardless!)

On Sat, Jan 21, 2017 at 8:43 AM, Ed Lazowska <lazowska@cs.washington.edu> wrote:
> birthday. (We are the same scary age.)

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Tuesday, April 11, 2017 10:14 AM

To: Marilyn Valentine;Paul Allen

Subject: The Golde letter

The Golde letter just arrived! What a prize!

Thanks so much!

From: Paul G. Allen <Paul@Vulcan.com>
Sent: Friday, December 16, 2016 3:16 PM
To: lazowska@cs.washington.edu
Subject: *****SPAM***** Happy Holidays!

Happy Holidays, Ed !

Paul G. Allen has sent you a holiday card. Please click here to view it.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Wednesday, March 29, 2017 11:27 AM
To: Paul Allen
Subject: Re: FW: Framed letter to Dr. Golde

That's a BEAUTY!

I would LOVE one for the Allen School archives!!!!!

On Wed, Mar 29, 2017 at 2:25 PM, Paul Allen <Paul@vulcan.com> wrote:
> Let me know if you want another copy!
>
> -----Original Message-----
> From: Marilyn Valentine
> Sent: Wednesday, March 29, 2017 7:23 PM
> To: Paul Allen <Paul@vulcan.com>
> Subject: Framed letter to Dr. Golde
>
> This is being sent to Dr. Golde today via courier. It turned out great! We had a high quality copy made that shows the wrinkles and folds. It looks really good in the frame.
>

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, April 25, 2017 7:01 AM
To: Paul Allen
Subject: Mozak in NY Times

99% chance you saw this online yesterday, but just in case - front page of hard-copy Science section this morning:

https://www.nytimes.com/2017/04/24/science/citizen-science-video-game-neurons.html

From: Paul Allen <Paul@vulcan.com>
Sent: Tuesday, November 8, 2016 11:52 AM
To: lazowska@cs.washington.edu
Cc: Bert Kolde;Allen Israel;Dave Stewart
Subject: RE: WOW!

Thanks Ed....any idea when you will want to announce, or when the dedication might happen? (don't know how these things are done, if there is a ceremony or not)?

-----Original Message-----
From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Monday, November 7, 2016 5:53 PM
To: Paul Allen <Paul@vulcan.com>
Cc: Bert Kolde <BertK@vulcan.com>; Allen Israel <allen.israel@foster.com>; Dave Stewart <DaveS@vulcan.com>
Subject: WOW!

I am completely speechless:

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THANK YOU!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, November 8, 2016 12:47 PM
To: Paul Allen
Cc: Bert Kolde;Allen Israel;Dave Stewart
Subject: Re: WOW!

Haven't had time to think about it!!!!!

But whatever it is, making it work best for you will be the top priority.

On Tue, Nov 8, 2016 at 12:42 PM, Paul Allen <Paul@vulcan.com> wrote:

> What is the meaning of "relatively soon"? anything formal where I give a speech might be next fall or? Late spring?
>
> **From:** Ed Lazowska [mailto:lazowska@cs.washington.edu]
> **Sent:** Tuesday, November 8, 2016 12:05 PM
> **To:** Paul Allen <Paul@vulcan.com>
> **Cc:** Bert Kolde <BertK@vulcan.com>; Allen Israel <allen.israel@foster.com>; Dave Stewart <DaveS@vulcan.com>
> **Subject:** Re: WOW!
>
> YOU BET there will be a ceremony!!!!!
>
> We'll work with Bert and Allen to come up with some possible scenarios for your consideration. I think we'll probably wind up de-coupling some things.
>
> Once it's brought to the Regents, it's "public" at some level. But maybe we can dance around that. The problem is that we have a lot of design work to do - for example, we need to have a logotype that we can live with for a long time, not something we whip together to meet a short-term deadline.
>
> But I think we'd like to do the ceremonial aspects of this relatively soon rather than waiting, because I don't want it to get tangled up with various things related to the building. This is separate. And this is going to be of national importance if we handle the announcement right ... the building is purely of local interest, but the creation of a named School is of much greater and broader significance.
>
> Anyway, once we catch our collective breath, we'll come up with some possible scenarios for your consideration, and together we can figure out how to roll it out.
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> And GO HAWKS. (Did you get the 747 model yet?)
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THANK YOU!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Sunday, April 23, 2017 8:13 PM

To: Paul Allen

Cc: John Pinette

Subject: An idea ...

Paul,

I wanted to float an idea and see if it had any appeal for you:

Most of our undergraduates participate either in faculty-supervised research or in senior-level "capstone design projects."

What would you think about a group of a half dozen of them visiting you at Vulcan and talking with you about their work and their experiences, some time in May?

This year will be the first in which students graduate from the Paul G. Allen School of Computer Science & Engineering. It would be an enormous thrill for some of our students to be able to speak with you, and it would give you insight into the undergraduate experience offered by the Allen School.

I'd *love* to set this up if you're interested!!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, November 8, 2016 12:05 PM
To: Paul Allen
Cc: Bert Kolde;Allen Israel;Dave Stewart
Subject: Re: WOW!

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> THANK YOU!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, January 8, 2017 7:57 AM
To: Paul Allen
Subject: Re: FW: WaveScalar update

GREAT GAME! Wow!

I have long since abandoned any notion that I can predict winners and losers.

PetraVM became Corensic, and released a product based on the deterministic multiprocessing technology - a concurrency testing tool. They had plans for another product, but F5 Networks bought the patents and the team. In a nutshell, Madrona lost patience pretty early.

Regarding WaveScalar, Mark tells me he still thinks about dataflow memory models and has a joint project with a professor at Technion Haifa (and a draft paper he'd be happy to send you if you want some bedtime reading!).

I'm just terrible at understanding the whys and wherefores of these things. I guess the problem is that I focus on the technology, and neat technology doesn't necessarily make a good business. I loved SNUPI/WallyHome - I have their stuff throughout my house - but Madrona sold the assets to Sears. Sears, though, has made a successful business out of it. Last July/August we had two exits: Impinj, which Madrona had kept alive for 16 years (!), IPOd and really seems to own the RFID space; Turi was acquired by Apple after only about a year of existence.

On Sat, Jan 7, 2017 at 11:35 AM, Paul Allen <Paul@vulcan.com> wrote:

> Neither of Oskin's projects seem to have taken off...any comment?
>
> Paul
>
> -----Original Message-----
> From: Jim Boyden [mailto:jim@jboyden.com]
> Sent: Monday, January 18, 2010 10:36 AM
> To: Paul Allen <Paul@vulcan.com>
> Subject: FW: WaveScalar update
>
> I decided to forward to you all of Mark's response rather than interpret it since it goes beyond WaveScalar into something that may or may not be of interest.
>
> -----Original Message-----
> From: Mark Oskin [mailto:markoskin@gmail.com] On Behalf Of Mark Oskin
> Sent: Monday, January 18, 2010 8:12 AM
> To: Jim Boyden
> Subject: Re: WaveScalar update
>
> Hi Jim-
>
> WaveScalar is paused until I return to academic life in the Fall of
> 2010 (8 months or so from now) I intend to pick it back up again.
> I've been thinking about what a "version 2" microarchitecture would look like and I believe it'd have the following features (distinct from the original design):
>
> - Aggressive memory alias speculation. Current systems are ~ 99% accurate on this, and I think coupling memory speculation with the out- of-order nature of execution WaveScalar has would be a big win

performance wise.

- A tad more centralization. The original microarchitecture was too extreme in its thinking about distributed designs. What happened with silicon since 2001 was not what people thought. Instead, clock rate fell over because future processes are denser, but the transistors are no faster. Hence, the need for such wide distribution of the microarchitecture is less. I wouldn't go all the way back to superscalar (which is very centralized), but I'd back away from the aggressive stance we took in "Version 1".

My current plan is to a sabbatical at UPC in 2010 - 2011 to work with Mateo and those guys to help refine the above two ideas. Then return to UW Fall of 2011 to start putting the team back together to research / build it.

As for Petra, we are still going strong. In fact, we are very close to getting our beta out the door. There's a nifty online demo Paul might be interested in watching at <http://petravm.com/jinx>. Our office is just across the Seahawks parking lot from Paul's office in fact, so if he'd like a demo of it in person I'm happy to walk over there and provide it. Here's one of our alpha customers and how they describe our product:

"As far as tools go, I have to say that for the type of work I do Jinx is kickin ass. I don't have much opportunity to use it at work (still not approved for install by IT (Edgar may be breaking the rules and using it), but at home I've fixed several work issues by Jinx'ing the code)
In my
personal codebase it is really kickin ass since when used in unit tests it almost always catches any goof I may make in my highly threaded codebase.
With atomic ops I've managed to run 2-3 times without Jinx flagging something but it almost always catches it eventually. We're talking about a
1 in a million case for the most part, so damned good that it gets caught.
:)"

That paragraph comes from a guy who works for a major games development company.

Best wishes,

-Mark

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Tuesday, September 13, 2016 9:59 PM

To: Paul Allen

Subject: Wednesday evening

Are you going to the Tedeschi/Trucks show at McCaw Hall??

From: Paul Allen <Paul@vulcan.com>
Sent: Thursday, April 13, 2017 1:29 PM
To: lazowska@cs.washington.edu
Subject: RE: Kildall's book

Thx much for sending the book.

There was a strange meeting at Boeing field where Gary (and Rolander?) flew up to pitch me and Bill on divvying up the market for languages and Oses.
Gary said "You guys can have languages, but let us have the OS market", Bill and I didn't agree, but not sure that's in his book?

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Thursday, April 13, 2017 1:24 PM
To: Paul Allen <Paul@vulcan.com>
Subject: Kildall's book

Paul,

Last night was phenomenal! Thanks so much for including me and Lyndsay.

I have two of the 20 copies of Gary Kildall's unpublished book. I'll send one down to you at Vulcan. Gary's is an incredibly sad story: many contributions, many successes, but drank himself to death lamenting what might have been and blaming others. (I think you'll agree, once you've read the book, that we're all fortunate it was not published ...)

Here's a web page from the dedication of the IEEE plaque. There's a photo of the bottom of Tom Rolander with Gary's son and daughter. We have a duplicate of the plaque in CSE - I asked IEEE to make one for us.

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https://news.cs.washington.edu/2015/06/12/tim-paterson-kevin-jeffay-receive-2015-uw-cse-alumni-achievement-awards/

Book will follow shortly. Thanks again!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Sunday, May 29, 2016 6:11 PM

To: Paul Allen

Subject: A Living Computer Museum question

Paul,

Are there instances in which mainframe systems at the Living Computer Museum were restored by teams that included people who had been system engineers when those models were in operation? For example, were there any CDC SE's involved in the 6500 restoration? Or IBM SE's in the /360-20 restoration? Or DEC SE's in the PDP-10 restoration?

(We had our annual Seattle alum event there on Wednesday evening and this question came up.)

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, August 4, 2016 9:54 AM

To: Paul Allen

Subject: Thank you!!

Paul,

Thanks for the big box of wonderful mementos of the Odyssea adventure.

The book of photographs is truly stunning!! (Professional photographers have a gift!)

The trip is something Lyndsay and I will remember for a long, long time.

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Monday, October 17, 2016 12:58 PM

To: Paul Allen

Cc: Bert Kolde;Connie Kravas;Ana M. CAUCE

Subject: More re CSE2

Paul,

I'm sure that Bert has been sharing with you the responses that Connie Kravas and I have provided to questions that he has sent.

I tremendously value the fact that all of us can be candid with one another - something that goes back many years. My professional life has focused on building one of the nation's and the world's most exceptional computer science programs right here at the University of Washington. The Paul G. Allen Center has been the single biggest enabler of that goal in my 38 years on the faculty. We are now ready to take the next step, and we deeply want your involvement.

As I explained to Bert, the idea of assembling a $30M consortium to name the building for Gates was a desperation attempt by Brad Smith to help me assemble naming-level funding in the absence of a single naming-level donor. I was skeptical that it would work, but it quickly became clear that the idea had real traction, and we already have $15M committed, with additional promising solicitations scheduled for November. Several individuals, plus Microsoft, are willing to double their commitments in order to make this happen. ($10M of the $15M under the Gates scenario is a doubling of Microsoft's original $10M commitment. Multiple individuals comprise the other $5M.) Under that scenario, we would have an Allen Center, a Gates Center, and an overall "Allen/Gates Corridor" that is the major area of campus where UW CSE is located.

Bert has asked whether Microsoft would keep their second $10M "in" if the building were named for Paul. I asked Brad this question via email - he is in Morocco but got back to me. His response:

=====
If Microsoft is going to contribute more than the original $10 million, we logically should support a strategy that names buildings after each of our founders. It's basically as simple as that. Especially since they both got their start together using the resources of UW, what could be more fitting than to have a building named after each of them right next door to each other?
=====

I need your help in problem-solving here. As I noted earlier, I see two great possible paths forward. One is that you are willing to name the building for $30M, and we scrap the Gates plan and the current and future funding associated with it. The other is that you are willing to contribute to a building named for Bill (assuming we assemble the full $30M from the consortium) - just as Bill contributed $6.5M 15 years ago to a building ultimately named for you. (As I noted to Bert, I am confident that Bill will invest in the CSE2 building also, but not at the naming level - "Population Health" is the greatest intersection of his and UW's interests. And as I also noted, a contribution from Paul could either be part of the Gates consortium or separate from it. In either case, there would be a high-profile named space within the building.)

If you see other paths forward that seem possible, PLEASE let me know!

And, again, whatever the outcome, I'm eternally grateful for your support and engagement. The Allen Center has truly been the single greatest enabler of our success. The CSE2 project will take us to a new level.

Thank you.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, October 6, 2016 9:18 AM
To: Allen Israel;Bert Kolde;Paul Allen
Subject: Amazon commitment to UW CSE2 project

Allen, Bert, and Paul,

Here's some great news for friends of UW Computer Science & Engineering:

This morning at 8 a.m. we announced that Amazon has committed $10 million to the CSE2 project. This news is, of course, big for us, but it's even bigger than that: it represents a bellweather philanthropic commitment by Amazon to the future of our region.

I'm hugely encouraged and hugely gratified by the support we're receiving for CSE2 from companies, from individuals, and from the state. There are more announcements to come! We now have $86 million of the necessary $110 million committed. Yes, we still have a significant hill to climb, but we are a lot closer than we were just a few months ago. With friends like Microsoft, Amazon, and you, I'm confident we will get there. CSE2 will enable us to educate more of Washington's students for Washington's high-impact jobs and help ensure that our region remains at the forefront of computing innovation.

The UW Today news release, with a video and a great deal of additional information, is here:

http://www.washington.edu/news/2016/10/06/cse-gets-major-boost-with-10-million-donation-from-amazon/

Thanks so much for your loyalty to UW CSE! And, "Please tell your friends about our show":

http://www.cs.washington.edu/supportcse/cse2.

GO HUSKIES! (Can you tell I'm excited?)

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, April 14, 2016 10:50 AM

To: Paul Allen

Cc: Lyndsay Downs

Subject: Infinite thanks

Paul,

Lyndsay and I count our blessings most days, but seldom more than over the past two weeks. We're so fortunate to have been included on Odyssea: the people, the places, the music, the conversations, the new and old friends. Thank you for what was truly a once-in-a-lifetime experience for us - one that we'll be smiling about for years.

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Saturday, September 3, 2016 9:32 PM

To: Paul Allen

Subject: Great Elephant Census

AMAZING coverage of the devastating findings of the Great Elephant Census. Hopefully it will translate into action. Well done!!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, January 21, 2016 10:43 AM

To: Paul Allen

Subject: Happy ...

bday!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Wednesday, October 19, 2016 6:50 AM
To: Ana M. CAUCE;Paul Allen
Subject: Fwd: The Jane Report

fyi
---------- Forwarded message ----------
From: **Tom Daniel** <danielt@uw.edu>
Date: Wed, Oct 19, 2016 at 6:40 AM
Subject: Re: The Jane Report
To: Ed Lazowska <lazowska@cs.washington.edu>

Hi Ed

Thanks for asking. All is pretty much back to normal. Neurologists are going to try to figure out what the repeat bleed was all about.

T

> On Oct 18, 2016, at 9:03 PM, Ed Lazowska <lazowska@cs.washington.edu> wrote:
>
> What's the word on the home front??

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, January 10, 2016 1:06 PM
To: Paul Allen
Subject: Whew!

Nail-biter!!!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Monday, October 26, 2015 11:01 PM

To: Oren Etzioni;Paul Allen;Allan Jones;Steve Hall;Andy Hickl

Subject: Semantic Scholar

I just spent some time using Semantic Scholar. It's phenomenal - a huge step beyond anything that precedes it. And I've only just begun to explore its capabilities. It makes all sorts of incredibly useful connections - to co-authors, to related papers, etc. It's a goldmine.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, January 17, 2016 8:51 AM
To: Andy Connolly;Charles Simonyi;Alan Eustace;Paul Allen
Subject: "How (and Why) SpaceX Will Colonize Mars"

I just ran into this phenomenal (and phenomenally long) post from August. Probably you've seen it, but just in case not:

http://waitbutwhy.com/2015/08/how-and-why-spacex-will-colonize-mars.html

From: Paul Allen <Paul@vulcan.com>
Sent: Tuesday, January 17, 2017 5:24 PM
To: lazowska@cs.washington.edu;Oren Etzioni
Cc: Ravi Jain;Keith Rosema;Spencer Reeder;Bill Hilf
Subject: RE: Climate inner loop on code that was distributed

Wow, this is the kind of analysis I was hoping for...is Preston a prof or?

What is the 'Tera" machine?

-----Original Message-----
From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Tuesday, January 17, 2017 3:13 PM
To: Oren Etzioni <orene@allenai.org>
Cc: Ravi Jain <RaviJ@vulcan.com>; Paul Allen <Paul@vulcan.com>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
Subject: Re: Climate inner loop on code that was distributed

Here's another very detailed response. I apologize for not having time today to organize these.

---------- Forwarded message ----------
From: Preston Briggs <preston.briggs@gmail.com>
Date: Tue, Jan 17, 2017 at 4:22 PM
Subject: Re: Special request from Paul.
To: Ed Lazowska <lazowska@cs.washington.edu>
Cc: Carlo del Mundo <cdel@cs.washington.edu>

Fortran, yum!

In the old days, Kennedy and his students said "loop balance"
instead of "operational intensity"; but it's a useful notion whatever the name.
Unfortunately, it doesn't really speak to locality which is terrifically important.

Starting at the top, I would rework the loops to improve things.
First, let's make it more readable

```
do j=js-1,je+1
  do i=is-1,ie
    ubt_Cor(i,j) = 0.0
  enddo
enddo

do j=js-1,je
  do i=is-1,ie+1
    vbt_Cor(i,j) = 0.0
  enddo
enddo

do j=js-1,je+1
```

```
  do k=1,nz
    do i=is-1,ie
      ubt_Cor(i,j) = ubt_Cor(i,j) + wt_u(i,j,k) * U_Cor(i,j,k)
    enddo
  enddo
enddo

do j=js-1,je
  do k=1,nz
    do i=is-1,ie+1
      vbt_Cor(i,j) = vbt_Cor(i,j) + wt_v(i,j,k) * V_Cor(i,j,k)
    enddo
  enddo
enddo
```

[looking at the original code, a loop nest using vbt_Cor has been omitted]

```
do j=js,je
  do i=is-1,ie
    Cor_ref_u(i,j) = ((amer(i-1,j) * ubt_Cor(i-1,j) + cmer(i  ,j+1) * ubt_Cor(i  ,j+1))
                +  (bmer(i  ,j) * ubt_Cor(i  ,j) + dmer(i-1,j+1) *
ubt_Cor(i-1,j+1)))
  enddo
enddo
```

I'd say the code would run pretty well on a vector machine; indeed, it might have started life when vector machines were the norm.
To run well on a modern machine, we will probably have to do some reorganization.
Looking locally, at these loops only, not the rest of the program, I'd combine loops 1&3 and loops 2&4 and reorganize a bit, like this

```
do j=js-1,je+1
  do i=is-1,ie
    s = 0.0
    do k=1,nz
      s = s + wt_u(i,j,k) * U_Cor(i,j,k)
    enddo
    ubt_Cor(i,j) = s
  enddo
enddo

do j=js-1,je
  do i=is-1,ie+1
    s = 0.0
    do k=1,nz
      s = s + wt_v(i,j,k) * V_Cor(i,j,k)
    enddo
    vbt_Cor(i,j) = s
  enddo
enddo
```

Here the inner loops are dot products and execute approximately 1 flop per memory reference.
The win here is that s would be carried in a register across the inner loops.

I think it's more useful to think of memory refs instead of bytes, since everybody moves around (at least) 8 bytes at a time.

It might be more useful to think of it as one muladd for 2 mem refs, since many processors can do a multiply-accumulate in a single cycle.

So great, a big improvement over the original code (old was 1 muladd/4 refs).
and something that a sufficiently smart compiler could do.
(Kennedy's students wrote about it; Tera's compiler could certainly do it; I'm not sure about Cray's other compilers; I'm pessimistic about other modern compilers.)

But notice the accesses to wt_u, xt_v, U_Cor, and V_Cot.
They're all indexed (i,j,k), where the k index varies quickest.
In Fortran, this implies that each successive access to, say wt_u, has long stride and will provoke a cache miss (on most modern machines, though not the Tera). So a more useful summary of each loop nest is that it has a balance of 1 muladd per 2 cache misses.

On a distributed memory machine, when I say "cache miss", we are probably talking about a remote memory access.
And looking at the pattern of references, we know there's no opportunity for re-use. That is, each time we fetch a value from a remote processor, we'll glance at it once and throw it away.

We might be able to improve matters by looking more globally and reorganizing the arrays so that we could rewrite the problem indices as (k,i,j). This would be wonderfully profitable here, but might be problematic in other places. Such a big change would likely be beyond any (?) compiler; typically the programmer would have to plan the global layout early in the design of the program (and the authors have probably done this; they're no dummies).

Let's consider the 5th loop, the stencil:

```
do j=js,je
  do i=is-1,ie
    Cor_ref_u(i,j) = ((amer(i-1,j) * ubt_Cor(i-1,j) + cmer(i  ,j+1) * ubt_Cor(i  ,j+1))
                +  (bmer(i  ,j) * ubt_Cor(i  ,j) + dmer(i-1,j+1) *
ubt_Cor(i-1,j+1)))
  enddo
enddo
```

They've written it so the i index is innermost, which is great for reducing cache misses.
(we say all the arrays are accessed with a short stride, and we are able to re-use the cache lines so that several memory refs can be satisfied by a single cache miss).
Otherwise, there's no re-use of references to amer, bmer, cmer, and dmer, so no improvement is possible.
The refs to ubt_Cor are more interesting: there's reuse of values across both i and j iterations.
Here's it's possible (even easy) to rewrite the loop nest to hold many values of ubt_Cor in registers, thus avoid a number of memory references. The details wil depend on the target machine, but we can approach a loop balance of 1 muladd per ref, which sounds fine. But in terms of cache misses, we might see something like 2 muladds per cache miss (depending many details), which is not so great.

I mentioned above that the code would probably run well on a vector machine, approaching 100% utilization. That's because lots of the old iron had a "machine balance" of about 1 muladd per 3 memory references. A modern micro

might be more like 1 muladd per memory reference. So the mis-match between loop balance and machine balance leads to relatively poor performance on modern processors.
And if cache misses are accounted for, the machine balance of a modern processor might be closer to 30 muladds per cache miss, or worse.

Of course, the modern processors (and GPUs, even more so) are much quicker than the old vector machines. But on a code like this, they'll spend their time mostly idle, waiting for cache misses and remote reads. So instead of the 100% utilization of the vector processors, we'll see 100% utilization of the memory system and some tiny fraction of a micro's potential flops.

Up to this point in the code, that's all I can see.
I think a modern micro or GPU would both be pretty underutilized, both waiting on cache misses, local and remote.
I don't see a way to recast the computation as a matrix multiply (which has plenty of reuse).

Same for the 2nd example computation (that I've ignored 'til now).
While it has control flow to uglify things, it's just a triply-nested loop organized so that all the references are stride one (good), but no other re-use, so no opportunity for improvement.

I expect I've written far too much.
Maybe there's something you can use,

Preston

On Tue, Jan 17, 2017 at 4:56 PM, Oren Etzioni <orene@allenai.org> wrote:
> Paul, Ed (cc'd) kindly pinged a bunch of folks with related expertise
> at CSE, and here are the most informative replies (with my highlights added).
>
> I read the answers as agreeing with Ravi.
>
>
>
> ---------- Forwarded message ----------
>
> From: Carlo C del Mundo <cdel@cs.washington.edu>
>
>
>
>
>
>
>
>
> The short answer is: no, GPU acceleration won't accelerate overall
> application performance by 10-100x. The overall application is memory
> bound, so adding GPUs into the mix won't help as much.
>
>
>
> The longer answer: for certain kernels, yes, you can theoretically
> achieve a 10x speedup using the GPU. The big caveat is: only for certain kernels.
> Since the application is a mixture of "high operational intensity" and

> "low operational intensity" operations, your overall speedup is
> limited by the slowest portion (Amdahl's Law).
>
>
>
> To address Paul's questions, you'll be bottlenecked by communication
> (e.g., data transfer to/from processors) rather than the computation.
>
> The primary reason is that for every byte that you have to process,
> you only compute a handful of operations (say 1 floating operation).
>
> Using a GPU won't help in this case because cores are idle waiting for
> data
> -- but increasing memory bandwidth will.
>
>
>
> GPUs fare very well for high operational intensity regimes (100s of
> floating point operations per byte). Matrix multiplication is one
> example, and sure, if the app below can be recast as matrix
> multiplication, you can benefit from significant acceleration using
> vendor-accelerated linear algebra libraries (about ~10x improvement
> over a tuned multi-core CPU implementation). That improvement is only
> relative to that particular function, and doesn't translate to overall application speedup.
>
>
>
>
>
> ---------- Forwarded message ----------
>
> From: Rastislav Bodik <bodik@cs.washington.edu>
>
>
>
>
>
> This is not a matrix computation and does not have the memory reuse
> pattern of one. Mark is right that one should not try to reduce the
> computation to a matrix library.
>
>
>
> Instead, the computation is a stencil, as Ravi points out. The
> vertical integral is a degenerate stencil, too.
>
>
>
> GPU streaming should work well for this code but it won't help
> operational intensity unless another level of tiling is introduced.
>
> Given the complexity of the ocean model, another level of tiling may
> be hard to engineer but HPC experts like Brad Chamberlain might be

> able to shed some light into whether this should be attempted.
>
>
>
> Since the Fortran code is already optimized, manually porting it to
> GPUs may be painful. A good compiler from stencils to GPUs would help
> in achieving these optimizations and one candidate compiler is of course Halide.
>
>
>
> I am cc-ing Alvin, who recently wrote a paper on porting Fortran
> stencil codes to Halide. Perhaps he can already alvinize this ocean modeling code?
>
>
>
> In the last paragraph, Ravi talks about accessing remote memory. A
> typical optimization for this big bottleneck in stencil codes are
> ghost cells but the Fortran code from Ravi seems to be doing it
> already under the name "wide halos". The good news is that Halide
> should be able to perform this optimization automatically (PPoPP 2016).
>
>
>
> I don't see an easy way around the if statements, by the way. But as
> Mark said, the divergence is not a big deal.
>
>
>
> To me, the key question is whether the port to GPUs will be worth it.
>
> The code will likely remain bandwidth limited so it might be
> preferrable to stay with the multi-level cache hierarchy of an SMP?
>
> Luis, Mark, what do you think?
>
>
>
> --Ras
>
>
>
>
>
> Halide:
> http://cgo.org/cgo2015/event/halide-code-generation-for-image-processi
> ng-and-stencil-computation-in-halide/
>
>
>
> Alvin's stencil paper:
>
> https://homes.cs.washington.edu/~akcheung/papers/pldi16.pdf
>

>
>
> Ghost cells:
> http://ipcc.cs.uoregon.edu/lectures/lecture-8-stencil.pdf
>
>
>
> Halide PPoPP 2016:
> http://people.csail.mit.edu/tyler/papers/ppopp16.pdf
>
>
>
>

From: Paul Allen <Paul@vulcan.com>
Sent: Sunday, September 4, 2016 5:52 AM
To: lazowska@cs.washington.edu
Subject: RE: Great Elephant Census

Thanks Ed!

What's the latest on the new building?

Paul

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Sunday, September 4, 2016 5:32 AM
To: Paul Allen <Paul@vulcan.com>
Subject: Great Elephant Census

AMAZING coverage of the devastating findings of the Great Elephant Census. Hopefully it will translate into action. Well done!!

From: Paul G. Allen <Paul@Vulcan.com>
Sent: Friday, December 18, 2015 3:43 PM
To: lazowska@cs.washington.edu
Subject: *****SPAM***** Happy Holidays!

Happy Holidays, Ed !

Paul G. Allen has sent you a holiday card. Please click here to view it.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, October 1, 2015 9:56 AM
To: Paul Allen;Oren Etzioni
Subject: Washington Post

Wow! Phenomenal article! It's so great to see these efforts getting the national visibility they deserve!!

http://www.washingtonpost.com/sf/national/2015/09/30/brain/

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, January 17, 2017 8:20 PM
To: Paul Allen
Cc: Ravi Jain;Oren Etzioni;Keith Rosema;Spencer Reeder;Bill Hilf
Subject: Re: Climate inner loop on code that was distributed

In my view the top 3 "high performance systems utilized for science" people in the NW (and among the very best in the nation and world) are Burton Smith (now at Microsoft), David Callahan (now at Facebook), and Preston Briggs (now at Reservoir Labs). All 3 are CSE Affiliate Professors. Any would be great to involve.

Burton Smith <burtons@microsoft.com>
David Callahan <dcallahan@fb.com>
Preston Briggs <preston.briggs@gmail.com>

On Tue, Jan 17, 2017 at 8:12 PM, Paul Allen <Paul@vulcan.com> wrote:

> Should we invite Preston to our climate computing summit or?
>
> **From:** Ed Lazowska [mailto:lazowska@cs.washington.edu]
> **Sent:** Tuesday, January 17, 2017 4:56 PM
> **To:** Ravi Jain <RaviJ@vulcan.com>
> **Cc:** Paul Allen <Paul@vulcan.com>; Oren Etzioni <orene@allenai.org>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
>
> **Subject:** Re: Climate inner loop on code that was distributed
>
> Sorry to be slow - additional detail:
>
> Ken Kennedy is a now-deceased Rice faculty member who was the leading person in compiler technology for parallel scientific computing. Preston got a Ph.D. from Ken in 1992 and went to work for Tera Computer Company in Seattle, which later became Cray.
>
> Tera was started by Burton Smith, a superstar computer architect now at Microsoft. Burton's used DARPA funds to build a machine called the Denelcor HEP. Super-innovative, but only one was ever built. Then he spent a few years at 3-letter agencies in DC working on a new architecture. When it seemed ready to go, my UW CSE colleague Larry Snyder and I convinced him to move to Seattle to start a company to try to build it. That was the Tera.
>
> Expanding a bit on what Ravi said: There are three ways to deal with memory latency in very large scale parallel computers. You can use caches, but then you have a cache coherence problem. You can have massive interconnect bandwidth, but this is wildly expensive and ultimately not scalable. Burton's approach, in the Tera, was to have a cacheless architecture but to have 128 hardware contexts per processor. When a particular thread was unable to make progress because its data had not arrived, the processor would switch to another thread in a single machine cycle. It took really amazing compiler technology to find that many threads - that's where Preston came in. He's a killer parallel compiler guy. (David Callahan was the other killer parallel compiler guy at Tera - also a Ken Kennedy student.)
>
> The Tera, too, did not sell very well. At some point, Tera purchased Cray in a fire sale and changed its name to Cray. The Tera machine became a sideline for Cray. Things weren't going well, though, and the Cray board of directors had to choose between the Tera successor and the next machine from Frostbite Falls, and they chose the latter. At that point, Burton and Callahan moved to Microsoft, Preston moved to AMD, basically the great people from Tera scattered to winds. But all in Seattle.

The last laugh was that just as this was happening, the 3-letter agencies discovered that Burton's architecture was *phenomenal* at a set of "big data" intelligence applications involving traversing extremely large graph structures, which did not exhibit locality and thus ran very slowly on any cache-based architecture. So they tried to keep the architecture alive in two ways: (1) find commercial applications that would utilize it, and (2) find less expensive implementations. The big success in the latter vein was work at UW by Luis Ceze and Mark Oskin called Grappa. Grappa used an updated version of operating system techniques from 15 years before to get Tera/Cray performance out of commodity Intel processors running on a commodity interconnect - it was really amazing work.

Preston moved from AMD to Google to NVIDIA to Reservoir Labs, all the time serving as an Affiliate Professor in UW CSE.

I'm sure Preston would be delighted to speak with you if that would be useful/fun.

On Tue, Jan 17, 2017 at 6:38 PM, Ravi Jain <RaviJ@vulcan.com> wrote:

> As you might recall, Tera was a supercomputer manufacturer which in year 2000 bought Cray Research from SGI and changed its own name to Cray.
>
> I believe he is referring to the Tera MTA machine. The Tera MTA machine (later named Cray MTA) was a supercomputer with an architecture oriented towards large numbers of independent threads and fine-grained communication. Only a handful of the machines were ever deployed I believe.
>
> Preston was at one point at Google but I don't know him and not sure where he is currently..
>
> -----Original Message-----
> From: Paul Allen
> Sent: Tuesday, January 17, 2017 5:24 PM
> To: lazowska@cs.washington.edu; Oren Etzioni <orene@allenai.org>
> Cc: Ravi Jain <RaviJ@vulcan.com>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
> Subject: RE: Climate inner loop on code that was distributed
> Importance: High
>
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> From: Preston Briggs <preston.briggs@gmail.com>
> Date: Tue, Jan 17, 2017 at 4:22 PM
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To: Ed Lazowska <lazowska@cs.washington.edu>
Cc: Carlo del Mundo <cdel@cs.washington.edu>

Fortran, yum!

In the old days, Kennedy and his students said "loop balance"
instead of "operational intensity"; but it's a useful notion whatever the name.
Unfortunately, it doesn't really speak to locality which is terrifically important.

Starting at the top, I would rework the loops to improve things.
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do j=js-1,je+1
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  enddo
enddo

do j=js-1,je
  do i=is-1,ie+1
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  enddo
enddo

do j=js-1,je+1
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    do i=is-1,ie
      ubt_Cor(i,j) = ubt_Cor(i,j) + wt_u(i,j,k) * U_Cor(i,j,k)
    enddo
  enddo
enddo

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    do i=is-1,ie+1
      vbt_Cor(i,j) = vbt_Cor(i,j) + wt_v(i,j,k) * V_Cor(i,j,k)
    enddo
  enddo
enddo
```

[looking at the original code, a loop nest using vbt_Cor has been omitted]

```
do j=js,je
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machines were the norm.
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Looking locally, at these loops only, not the rest of the program, I'd combine loops 1&3 and loops 2&4 and reorganize a bit, like this

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    enddo
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enddo
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The win here is that s would be carried in a register across the inner loops.

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So great, a big improvement over the original code (old was 1 muladd/4 refs).
and something that a sufficiently smart compiler could do.
(Kennedy's students wrote about it; Tera's compiler could certainly do it; I'm not sure about Cray's other compilers; I'm pessimistic about other modern compilers.)

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They're all indexed (i,j,k), where the k index varies quickest.
In Fortran, this implies that each successive access to, say wt_u, has long stride and will provoke a cache miss (on most modern machines, though not the Tera). So a more useful summary of each loop nest is that it has a balance of 1 muladd per 2 cache misses.

On a distributed memory machine, when I say "cache miss", we are probably talking about a remote memory access. And looking at the pattern of references, we know there's no opportunity for re-use. That is, each time we fetch a value from a remote processor, we'll glance at it once and throw it away.

We might be able to improve matters by looking more globally and reorganizing the arrays so that we could rewrite the problem indices as (k,i,j). This would be wonderfully profitable here, but might be problematic in other places. Such a big change would likely be beyond any (?) compiler; typically the programmer would have to plan the global layout early in the design of the program (and the authors have probably

done this; they're no dummies).

Let's consider the 5th loop, the stencil:

```
do j=js,je
  do i=is-1,ie
    Cor_ref_u(i,j) = ((amer(i-1,j) * ubt_Cor(i-1,j) + cmer(i  ,j+1) * ubt_Cor(i  ,j+1))
                  +  (bmer(i  ,j) * ubt_Cor(i  ,j) + dmer(i-1,j+1) *
ubt_Cor(i-1,j+1)))
  enddo
enddo
```

They've written it so the i index is innermost, which is great for reducing cache misses.
(we say all the arrays are accessed with a short stride, and we are able to re-use the cache lines so that several memory refs can be satisfied by a single cache miss).
Otherwise, there's no re-use of references to amer, bmer, cmer, and dmer, so no improvement is possible.
The refs to ubt_Cor are more interesting: there's reuse of values across both i and j iterations.
Here's it's possible (even easy) to rewrite the loop nest to hold many values of ubt_Cor in registers, thus avoid a number of memory references. The details wil depend on the target machine, but we can approach a loop balance of 1 muladd per ref, which sounds fine. But in terms of cache misses, we might see something like 2 muladds per cache miss (depending many details), which is not so great.

I mentioned above that the code would probably run well on a vector machine, approaching 100% utilization. That's because lots of the old iron had a "machine balance" of about 1 muladd per 3 memory references. A modern micro might be more like 1 muladd per memory reference. So the mis-match between loop balance and machine balance leads to relatively poor performance on modern processors.
And if cache misses are accounted for, the machine balance of a modern processor might be closer to 30 muladds per cache miss, or worse.

Of course, the modern processors (and GPUs, even more so) are much quicker than the old vector machines. But on a code like this, they'll spend their time mostly idle, waiting for cache misses and remote reads. So instead of the 100% utilization of the vector processors, we'll see 100% utilization of the memory system and some tiny fraction of a micro's potential flops.

Up to this point in the code, that's all I can see.
I think a modern micro or GPU would both be pretty underutilized, both waiting on cache misses, local and remote.
I don't see a way to recast the computation as a matrix multiply (which has plenty of reuse).

Same for the 2nd example computation (that I've ignored 'til now).
While it has control flow to uglify things, it's just a triply-nested loop organized so that all the references are stride one (good), but no other re-use, so no opportunity for improvement.

I expect I've written far too much.
Maybe there's something you can use,

Preston

On Tue, Jan 17, 2017 at 4:56 PM, Oren Etzioni <orene@allenai.org> wrote:
> Paul, Ed (cc'd) kindly pinged a bunch of folks with related expertise

> at CSE, and here are the most informative replies (with my highlights added).
>
> I read the answers as agreeing with Ravi.
>
>
>
> ---------- Forwarded message ----------
>
> From: Carlo C del Mundo <cdel@cs.washington.edu>
>
>
>
>
>
>
>
>
> The short answer is: no, GPU acceleration won't accelerate overall
> application performance by 10-100x. The overall application is memory
> bound, so adding GPUs into the mix won't help as much.
>
>
>
> The longer answer: for certain kernels, yes, you can theoretically
> achieve a 10x speedup using the GPU. The big caveat is: only for certain kernels.
> Since the application is a mixture of "high operational intensity" and
> "low operational intensity" operations, your overall speedup is
> limited by the slowest portion (Amdahl's Law).
>
>
>
> To address Paul's questions, you'll be bottlenecked by communication
> (e.g., data transfer to/from processors) rather than the computation.
>
> The primary reason is that for every byte that you have to process,
> you only compute a handful of operations (say 1 floating operation).
>
> Using a GPU won't help in this case because cores are idle waiting for
> data
> -- but increasing memory bandwidth will.
>
>
>
> GPUs fare very well for high operational intensity regimes (100s of
> floating point operations per byte). Matrix multiplication is one
> example, and sure, if the app below can be recast as matrix
> multiplication, you can benefit from significant acceleration using
> vendor-accelerated linear algebra libraries (about ~10x improvement
> over a tuned multi-core CPU implementation). That improvement is only
> relative to that particular function, and doesn't translate to overall application speedup.
>
>
>
>
>

> ---------- Forwarded message ----------
>
> From: Rastislav Bodik <bodik@cs.washington.edu>
>
>
>
>
>
> This is not a matrix computation and does not have the memory reuse
> pattern of one. Mark is right that one should not try to reduce the
> computation to a matrix library.
>
>
>
> Instead, the computation is a stencil, as Ravi points out. The
> vertical integral is a degenerate stencil, too.
>
>
>
> GPU streaming should work well for this code but it won't help
> operational intensity unless another level of tiling is introduced.
>
> Given the complexity of the ocean model, another level of tiling may
> be hard to engineer but HPC experts like Brad Chamberlain might be
> able to shed some light into whether this should be attempted.
>
>
>
> Since the Fortran code is already optimized, manually porting it to
> GPUs may be painful. A good compiler from stencils to GPUs would help
> in achieving these optimizations and one candidate compiler is of course Halide.
>
>
>
> I am cc-ing Alvin, who recently wrote a paper on porting Fortran
> stencil codes to Halide. Perhaps he can already alvinize this ocean modeling code?
>
>
>
> In the last paragraph, Ravi talks about accessing remote memory. A
> typical optimization for this big bottleneck in stencil codes are
> ghost cells but the Fortran code from Ravi seems to be doing it
> already under the name "wide halos". The good news is that Halide
> should be able to perform this optimization automatically (PPoPP 2016).
>
>
>
> I don't see an easy way around the if statements, by the way. But as
> Mark said, the divergence is not a big deal.
>
>
>
> To me, the key question is whether the port to GPUs will be worth it.
>

> The code will likely remain bandwidth limited so it might be
> preferrable to stay with the multi-level cache hierarchy of an SMP?
>
> Luis, Mark, what do you think?
>
>
>
> --Ras
>
>
>
>
>
> Halide:
> http://cgo.org/cgo2015/event/halide-code-generation-for-image-processi
> ng-and-stencil-computation-in-halide/
>
>
>
> Alvin's stencil paper:
>
> https://homes.cs.washington.edu/~akcheung/papers/pldi16.pdf
>
>
>
> Ghost cells:
> http://ipcc.cs.uoregon.edu/lectures/lecture-8-stencil.pdf
>
>
>
> Halide PPoPP 2016:
> http://people.csail.mit.edu/tyler/papers/ppopp16.pdf
>
>
>
>

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, December 3, 2015 7:40 PM
To: Paul Allen;Allen Israel;Bert Kolde
Subject: LMN Architects

Paul, Allen, and Bert,

LMN Architects, the designers of the Paul G. Allen Center (and of our new building, and of UW's PACCAR Hall, and of Benaroya Hall, and of McCaw Hall), have just been named as the recipient of this year's major AIA award:

http://www.architectmagazine.com/awards/aia-honor-awards/lmn-architects-wins-the-2016-aia-architecture-firm-award_o

This is wonderful recognition - this firm is *really* good.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, April 24, 2016 1:13 PM
To: Paul Allen
Subject: Fwd: Tedeschi and Trucks coming to Seattle!

We're in there!!

---------- Forwarded message ----------
From: **Carole Horwitz** <crhorwitz@gmail.com>
Date: Sun, Apr 24, 2016 at 12:50 PM
Subject: Tedeschi and Trucks coming to Seattle!
To: cauce@uw.edu, Susan J <susanj@u.washington.edu>, chinhda@alleninstitute.org, allen.isreal@foster.com, larry.felser@gmail.com, lazowska@cs.washington.edu

Just heard on the radio that they fit Seattle into their tour schedule and will be at McCaw Hall on September 14. We will be out of town, but wanted to pass along the news. So disappointed to miss it. Hope you are able to go and tell us about it!

Carole and Rick

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Monday, April 4, 2016 9:27 AM

To: Paul Allen

Subject: WOW!!!!!

Best night of music EVER!!!!!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, November 5, 2015 6:34 AM
To: Paul Allen
Subject: Dinner on December 7?

Paul,

Are you available for dinner with Alan Eustace on December 7?

Alan - recently retired from Google - will be delivering the UW CSE Distinguished Lecture on December 8, describing his world record freefall skydive from 136,000 feet. He's great company, and the skydive was both great science and a great adventure.

We'd love to have you join for dinner on December 7 - and also for Alan's talk on December 8 if you can make that.

Please let me know. You will really enjoy Alan, and your overlapping interests in space will spark lots of conversation.

http://www.cs.washington.edu/events/colloquia/details?id=2775

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, December 1, 2015 12:28 PM
To: Ali Farhadi;Oren Etzioni;Paul Allen
Subject: Learning like babies

Some work by Raj Rao and Andy Meltzoff; perhaps relevant??

UW news release from this morning.

http://www.washington.edu/news/2015/12/01/uw-roboticists-learn-to-teach-robots-from-babies/

From: Paul Allen <Paul@vulcan.com>
Sent: Friday, January 8, 2016 10:17 PM
To: Ed Lazowska
Subject: FW: Seattle News and Events | Time Bomb: Clock May Be Ticking for UW's

Where do you think this will come out?

Seattle News and Events | Time Bomb: Clock May Be Ticking for UW's -
http://www.seattleweekly.com/news/962138-129/time-bomb-clock-may-be-ticking

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Tuesday, August 25, 2015 10:59 AM

To: Paul Allen

Subject: 2015 Carnegie Medal of Philanthropy

Oren just told me. Congratulations - long overdue.

(Do you know Irwin Jacobs, another recipient this year? Another phenomenal tech person - you'll really like him.)

From: Paul Allen <Paul@vulcan.com>
Sent: Monday, January 11, 2016 9:12 PM
To: Ed Lazowska
Subject: RE: Whew!

yup, frozen one!

-----Original Message-----
From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Sunday, January 10, 2016 1:06 PM
To: Paul Allen <Paul@vulcan.com>
Subject: Whew!

Nail-biter!!!

From: Paul Allen <Paul@vulcan.com>
Sent: Monday, October 26, 2015 11:15 PM
To: Ed Lazowska;Oren Etzioni;Allan Jones (AIBS);Stephen Hall;Andy Hickl
Subject: RE: Semantic Scholar

Great! Please send along any ideas on what are the most important features we need to add, etc....

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Monday, October 26, 2015 11:01 PM
To: Oren Etzioni <OrenE@allenai.org>; Paul Allen <Paul@vulcan.com>; Allan Jones (AIBS) <AllanJ@alleninstitute.org>; Stephen Hall <StephenHa@vulcan.com>; Andy Hickl <AndyH@vulcan.com>
Subject: Semantic Scholar

I just spent some time using Semantic Scholar. It's phenomenal - a huge step beyond anything that precedes it. And I've only just begun to explore its capabilities. It makes all sorts of incredibly useful connections - to co-authors, to related papers, etc. It's a goldmine.

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, June 11, 2015 6:27 AM

To: Paul Allen

Subject: Special news from UW CSE - embargoed until 8 p.m. tonight

Paul,

I want to share some UW Computer Science & Engineering news with you before it goes public. (Please note that this news is embargoed until THURSDAY NIGHT - TONIGHT - AT 8 P.M. – please don't share it before then.)

On Friday evening at the CSE graduation ceremony, Brad Smith, Microsoft general counsel and executive vice president, will announce that Microsoft is making a $10 million gift towards the construction of an additional building for UW CSE.

Microsoft's gift represents the first corporate commitment to a public-private partnership to assemble $110 million in funding to construct a new 130,000-square-foot CSE building. The new facility will provide the space needed to double the number of degrees we award annually, and dramatically expand our research, collaboration, and entrepreneurship. Microsoft provided the first corporate gift for the Paul G. Allen Center for Computer Science & Engineering; we can't thank them enough for once again leading the way.

You and Microsoft were the keys to making our current building happen - a building that has been central to UW CSE becoming truly one of the nation's top computer science programs. And of course the partnership between you and UW goes back to way before my time - to the pre-Microsoft days when you were a student at Lakeside and roamed UW's computing facilities.

$110 million is a steep hill to climb – we have a long way to go. Several major individual gifts have already been received though, and with this gift from Microsoft our campaign goes public. UW CSE desperately needs to expand. Student demand and employer demand both are extraordinary. Kids who grow up in the state of Washington deserve the opportunity to be educated for jobs at the forefront of our region's innovation economy. That's what we do.

Thanks so much for your interest and support over the years!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Wednesday, August 26, 2015 2:07 PM
To: Paul Allen
Subject: Alan Eustace

Paul,

You might be interested in this talk on December 8:

http://www.cs.washington.edu/events/colloquia/details?id=2775

(Alan Eustace is ex-DEC, ex-Google, recently skydived from a balloon at 135,890 feet, breaking the world's record.)

Also, Alan expects to be here for dinner on December 7. If you'd be interested in joining, that'd be fantastic.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Saturday, January 9, 2016 8:30 AM
To: Paul Allen
Subject: Re: FW: Seattle News and Events | Time Bomb: Clock May Be Ticking for UW's

Paul,

Best discuss this on the phone, if you can find 5 minutes. Please let me know what might work.

The short version: We continue to be optimistic that we can use the preferred site, while appropriately honoring More Hall Annex.

On Fri, Jan 8, 2016 at 10:16 PM, Paul Allen <Paul@vulcan.com> wrote:

> Where do you think this will come out?
>
> Seattle News and Events | Time Bomb: Clock May Be Ticking for UW's -
> http://www.seattleweekly.com/news/962138-129/time-bomb-clock-may-be-ticking

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, June 23, 2015 11:27 AM
To: Paul Allen
Subject: Thanks

Paul,

I want to thank you for the time and effort that you, Bert, and Allen devoted to considering UW's proposal. We appreciate it greatly.

I've been trying to schedule a time for you to visit to see some of the newer work that's going on here. Any chance? (Or, we could come to
you.) We've branched out in a number of new directions that I know you'd find interesting. We'd be really excited to be able to describe some of it to you.

Thanks again. See you before too long, either here or at AI2.

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, September 10, 2015 9:22 AM
To: Oren Etzioni;Paul Allen
Subject: What a phenomenal article!!

http://www.technologyreview.com/news/541001/ai-software-goes-up-against-fourth-graders-on-science-tests/

From: Paul Allen <Paul@vulcan.com>
Sent: Thursday, January 21, 2016 10:51 AM
To: Ed Lazowska
Subject: RE: Happy ...

Thanks Ed!

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Thursday, January 21, 2016 10:43 AM
To: Paul Allen <Paul@vulcan.com>
Subject: Happy ...

bday!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Monday, June 6, 2016 6:20 AM
To: Oren Etzioni;Paul Allen
Subject: Forbes article

Wow! Great interview!

http://www.forbes.com/sites/peterhigh/2016/06/06/the-serial-entrepreneur-who-leads-paul-allens-ai-institute/

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Tuesday, March 31, 2015 9:51 AM

To: Ada Healey;Paul Allen

Subject: U District construction

Ada and Paul,

I realize that you need to make a hard-nosed business decision regarding whether to build residential units or tech space on your U District land - Vulcan Real Estate is a (very successful!) business!

There is an opportunity, though, to re-make the U District into the next South Lake Union, with fewer head shops and crummy restaurants, more startups and R&D facilities, and the light rail station that will open towards the end of this decade.

UW has taken some risks in this regard, such as converting one floor of the former Law School building, Condon Hall, into "Startup Hall" (anchored by Chris DeVore's TechStars), and committing to lease 40% of the tech space that you might build. I truly believe that we can attract to the U District a number of local and out-of-state startups and R&D facilities that can make this pencil out. A long list of tech companies, from Google Seattle a decade ago to Uber last month, would have launched in the U District if there had been suitable space. (Plus AI2!) I don't see why the future shouldn't be even brighter than the past - and organizations that launch in a Vulcan property in the U District could be transitioned to other Vulcan properties elsewhere as they grow.

Needless to say, I know NOTHING about business, particularly real estate! But I just wanted to weigh in regarding the opportunity that I perceive.

Thanks!!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, March 12, 2015 6:13 PM

To: Paul Allen

Subject: WOW WOW WOW!

The Musashi live feed is FANTASTIC!

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Wednesday, March 4, 2015 7:05 AM

To: Paul Allen

Subject: Musashi

Wow! Incredibly exciting. And, talk about finding a needle in a haystack!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, August 25, 2015 9:31 PM
To: Paul Allen
Subject: Re: 2015 Carnegie Medal of Philanthropy

Three overlaps with Irwin and Joan Jacobs:

- Irwin, obviously, is Qualcomm - his son Paul runs it now. I first met Irwin through the National Academy of Engineering. He's super-smart, and also just a wonderful human being. You will really like him.

- They are very substantial patrons of the arts. The guy who briefly was the head of SAM a few years ago, Derrick Cartwright, had previously been the head of a San Diego museum that Irwin and Joan had bankrolled; at one point when Irwin was up here to give a Distinguished Lecture in UW CSE, Derek and his wife joined us for a dinner with Irwin and Joan. Irwin and Joan will be really interested in the Art Fair that you created.

- Irwin named the Jacobs School of Engineering at UC San Diego, which has done phenomenally well. (His colleague Andy Viterbi named USC's School of Engineering, which has gone nowhere - money alone can't buy success!). More recently, he bankrolled the Cornell/Technion collaborative effort in NYC.

Status of our building:

- $32.5M from the Legislature.
- $10.0M from Microsoft.
- A small number of other gifts (explanation below).
- ~$65M still needed.

We are just getting moving, to be honest. I had a call with Brad Smith (Microsoft) today, who is chairing our development committee. We have a plan going forward. There have been some complexities in approaching possible game-changing donors (Gates, Ballmer, Bezos, etc.) but we have resolved those and are now going to move ahead. This will not be a cake-walk: lots of people have other priorities, and lots of people believe that others will support us. But we will get there.

We need to set the "School" aside for the time being. While it is extremely important, the building is even more important in the near term: it is essential to enabling us to graduate more students ("Washington students for Washington jobs"), and to hire more game-changing faculty.

That's the scoop.

On Tue, Aug 25, 2015 at 3:51 PM, Paul Allen <Paul@vulcan.com> wrote:

> Thanks Ed!
> No I don't know Irwin, should be interesting to meet some of the other award winners.
>
> Curious if there is any more news on the CSEE building?
>
> **From:** Ed Lazowska [mailto:lazowska@cs.washington.edu]
> **Sent:** Tuesday, August 25, 2015 6:59 PM
> **To:** Paul Allen <Paul@vulcan.com>
> **Subject:** 2015 Carnegie Medal of Philanthropy
>
> Oren just told me. Congratulations - long overdue.
>
> (Do you know Irwin Jacobs, another recipient this year? Another phenomenal tech person - you'll really like him.)

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Monday, September 5, 2016 6:52 AM
To: Paul Allen
Cc: Tom Daniel;Keith Rosema;Ravi Jain
Subject: Re: FW: Friday Harbor Lab Summer Course

Phenomenal!!

On Mon, Sep 5, 2016 at 3:00 AM, Paul Allen <Paul@vulcan.com> wrote:

> Just FYI...Paul
>
> From: Christof Koch [mailto:ChristofK@alleninstitute.org]
> Sent: Sunday, September 4, 2016 10:26 PM
> To: Paul Allen <Paul@vulcan.com>; Allan Jones (AIBS) <AllanJ@alleninstitute.org>
> Subject: Friday Harbor Lab Summer Course
>
> Hi Paul and Allen,
>
> We just finished our two week long very intensive, summer course "The Dynamic Brain" at UW's Friday harbor Laboratory on San Juan Island. The 24 students (senior graduate students and post-docs, supported by 12 faculty and staff) really took to the "Allen Brain Observatory" data set to our jupyter notebooks like fish to water.
>
> Their projects were among the best I've seen in 25 years of teaching 'computational neuroscience' summer courses.
>
> We'll try to continue to work with some of them (last year, a paper was published based on one a summer course project).
>
> See our short blog with some photos here
>
> http://compneuro.washington.edu/the-dynamic-brain/
>
> Christof
> --
> Dr. Christof Koch<http://www.alleninstitute.org/our-science/brain-science/about/team/staff-profile/christof-koch>
> President and Chief Scientific Officer
>
> [cid:image001.png@01D20764.C1F15B70]
>
> Allen Institute for Brain Science<http://www.alleninstitute.org/>, Seattle

From: Paul Allen <Paul@vulcan.com>
Sent: Tuesday, May 5, 2015 1:18 AM
To: Ed Lazowska
Subject: RE: NY Times

Thanks!

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Tuesday, May 5, 2015 12:14 AM
To: Paul Allen
Subject: NY Times

Great profile by Nick Wingfield!!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, April 9, 2015 9:57 PM
To: Paul Allen
Subject: Another quick update

Paul,

Roughly half of our faculty additions in the past few years have been in "outward-looking" areas: machine learning, computer vision, natural language processing, etc.

But we have not forsaken the core of the field, which is the foundation of our ability to extend to national and global societal priorities. Our most recent hire - just confirmed yesterday - is a great example. We stole from Berkeley a full professor who is the top person nationally in programming languages:

https://news.cs.washington.edu/2015/04/07/ras-bodik-joins-uw-cse-creating-a-world-class-programming-languages-group/

Here's an email we received from an east coast colleague:

=====
From: Henry Kautz
Sent: Wednesday, April 08, 2015 7:54 AM
To: Paul Beame; Dan Weld; Hank Levy; Ed Lazowska
Subject: Fwd: UW could make it to top 4 ...

I guess Berkeley, CMU, Cornell, and CMU are just "farm teams" for UW now!
=====

We're not there yet, but we can get there!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, October 4, 2016 5:44 PM
To: Paul Allen
Subject: Arati Prabhakar, Thursday at 3:30

Paul,

I can't imagine you're free on Thursday at 3:30, but on the off chance, since she used to work for you at Interval Research and is *really* smart:

http://www.cs.washington.edu/events/colloquia/details?id=2918

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, August 4, 2016 9:55 AM
To: Paul Allen
Subject: Fwd: Clip (July 19 2016 at 126 PM).mp4

In other news, this 2-minute video illustrates some momentous progress on our end ...

---------- Forwarded message ----------
From: **Aaron Timss (via Google Drive)** <drive-shares-noreply@google.com>
Date: Wed, Jul 20, 2016 at 10:15 AM
Subject: Clip (July 19 2016 at 126 PM).mp4
To: lazowska@cs.washington.edu
Cc: levy@cs.washington.edu, tracy@cs.washington.edu

Aaron Timss has shared the following video:

Clip (July 19 2016 at 126 PM).mp4
Open

Logo for Google Drive

Google Drive: Have all your files within reach from any device.
Google Inc. 1600 Amphitheatre Parkway, Mountain View, CA 94043, USA

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Monday, May 4, 2015 9:14 PM

To: Paul Allen

Subject: NY Times

Great profile by Nick Wingfield!!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Sunday, September 4, 2016 8:15 AM
To: Paul Allen
Subject: Re: Great Elephant Census

Thanks for asking about the building!

The good news:

- The nuclear reactor building is history, so the site is ours - there's a short video of the end-game here:
https://drive.google.com/file/d/0B8xM-oMN8Mifd3QyWlp0eFJfRjA/view?ts=578fb199

- The design for CSE2 is nearly complete, and it's really excellent - LMN has done a terrific job for us. Some images are here:
http://www.cs.washington.edu/supportcse/campaign

- State legislator Drew Hansen is hell-bent on getting us the second half of the enrollment funding that will enable us to double our degrees/year (the first half arrived this biennium).

- Student demand continues to be extraordinary - for example:
https://news.cs.washington.edu/2016/06/24/top-10-first-choice-majors-of-uw-confirmed-incoming-freshmen-2016-edition/
(We taught 3,000 students in our "CS1" intro course last year, and 2,000 students in our "CS2" second course!)

- Brad Smith (Microsoft), who is leading our fundraising group, has been a saint. And others are playing important roles - for example, Charles Simonyi and his wife hosted an event for us, and Charles flew me down to the Bay Area last weekend so we could speak with several prospective donors.

- We have $76M committed, of the necessary $110M. (This includes a $10M commitment that will be announced in 2 weeks, and an unannounced increase in another already-generous commitment.)

- We have a number of irons in the fire, and several events for potential donors in the next few weeks - here and in the Bay Area.

The bad news:

- We don't have a naming-level donor, which means we are piecing this together - multiple major gifts at less than a naming level.

- To keep the project on schedule (meaning breaking ground in January), we need to obtain commitments for roughly 70% of the remaining $34M during 2016. Cash flow is not a problem - we have enough cash to get going, and we have enough reserves to fund bridge loans - so the commitments can be pledges extending over multiple years. But because various parts of UW are under financial strain (Law, Dentistry, Athletics, others), the Regents have understandably become extremely conservative; "Trust me, we'll come up with the money" is not going to work. If we can't document roughly $100M in funds+pledges to the Regents by the end of 2016, the project is going to get delayed.

So I have a busy 4 months ahead. But Brad keeps me optimistic.

On Sun, Sep 4, 2016 at 5:52 AM, Paul Allen <Paul@vulcan.com> wrote:

> Thanks Ed!
>
> What's the latest on the new building?

Paul

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Sunday, September 4, 2016 5:32 AM
To: Paul Allen <Paul@vulcan.com>
Subject: Great Elephant Census

AMAZING coverage of the devastating findings of the Great Elephant Census. Hopefully it will translate into action. Well done!!

From: Paul Allen <Paul@vulcan.com>
Sent: Tuesday, August 25, 2015 3:51 PM
To: Ed Lazowska
Subject: RE: 2015 Carnegie Medal of Philanthropy

Thanks Ed!
No I don't know Irwin, should be interesting to meet some of the other award winners.

Curious if there is any more news on the CSEE building?

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Tuesday, August 25, 2015 6:59 PM
To: Paul Allen <Paul@vulcan.com>
Subject: 2015 Carnegie Medal of Philanthropy

Oren just told me. Congratulations - long overdue.

(Do you know Irwin Jacobs, another recipient this year? Another phenomenal tech person - you'll really like him.)

From: Paul Allen <Paul@vulcan.com>
Sent: Tuesday, January 17, 2017 8:13 PM
To: lazowska@cs.washington.edu;Ravi Jain
Cc: Oren Etzioni;Keith Rosema;Spencer Reeder;Bill Hilf
Subject: RE: Climate inner loop on code that was distributed

Should we invite Preston to our climate computing summit or?

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Tuesday, January 17, 2017 4:56 PM
To: Ravi Jain <RaviJ@vulcan.com>
Cc: Paul Allen <Paul@vulcan.com>; Oren Etzioni <orene@allenai.org>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
Subject: Re: Climate inner loop on code that was distributed

Sorry to be slow - additional detail:

Ken Kennedy is a now-deceased Rice faculty member who was the leading person in compiler technology for parallel scientific computing. Preston got a Ph.D. from Ken in 1992 and went to work for Tera Computer Company in Seattle, which later became Cray.

Tera was started by Burton Smith, a superstar computer architect now at Microsoft. Burton's used DARPA funds to build a machine called the Denelcor HEP. Super-innovative, but only one was ever built. Then he spent a few years at 3-letter agencies in DC working on a new architecture. When it seemed ready to go, my UW CSE colleague Larry Snyder and I convinced him to move to Seattle to start a company to try to build it. That was the Tera.

Expanding a bit on what Ravi said: There are three ways to deal with memory latency in very large scale parallel computers. You can use caches, but then you have a cache coherence problem. You can have massive interconnect bandwidth, but this is wildly expensive and ultimately not scalable. Burton's approach, in the Tera, was to have a cacheless architecture but to have 128 hardware contexts per processor. When a particular thread was unable to make progress because its data had not arrived, the processor would switch to another thread in a single machine cycle. It took really amazing compiler technology to find that many threads - that's where Preston came in. He's a killer parallel compiler guy. (David Callahan was the other killer parallel compiler guy at Tera - also a Ken Kennedy student.)

The Tera, too, did not sell very well. At some point, Tera purchased Cray in a fire sale and changed its name to Cray. The Tera machine became a sideline for Cray. Things weren't going well, though, and the Cray board of directors had to choose between the Tera successor and the next machine from Frostbite Falls, and they chose the latter. At that point, Burton and Callahan moved to Microsoft, Preston moved to AMD, basically the great people from Tera scattered to winds. But all in Seattle.

The last laugh was that just as this was happening, the 3-letter agencies discovered that Burton's architecture was *phenomenal* at a set of "big data" intelligence applications involving traversing extremely large graph structures, which did not exhibit locality and thus ran very slowly on any cache-based architecture. So they tried to keep the architecture alive in two ways: (1) find commercial applications that would utilize it, and (2) find less expensive implementations. The big success in the latter vein was work at UW by Luis Ceze and Mark Oskin called Grappa. Grappa used an updated version of operating system techniques from 15 years before to get Tera/Cray performance out of commodity Intel processors running on a commodity interconnect - it was really amazing work.

Preston moved from AMD to Google to NVIDIA to Reservoir Labs, all the time serving as an Affiliate Professor in UW CSE.

I'm sure Preston would be delighted to speak with you if that would be useful/fun.

On Tue, Jan 17, 2017 at 6:38 PM, Ravi Jain <RaviJ@vulcan.com> wrote:

> As you might recall, Tera was a supercomputer manufacturer which in year 2000 bought Cray Research from SGI and changed its own name to Cray.
>
> I believe he is referring to the Tera MTA machine. The Tera MTA machine (later named Cray MTA) was a supercomputer with an architecture oriented towards large numbers of independent threads and fine-grained communication. Only a handful of the machines were ever deployed I believe.
>
> Preston was at one point at Google but I don't know him and not sure where he is currently..
>
> -----Original Message-----
> From: Paul Allen
> Sent: Tuesday, January 17, 2017 5:24 PM
> To: lazowska@cs.washington.edu; Oren Etzioni <orene@allenai.org>
> Cc: Ravi Jain <RaviJ@vulcan.com>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
> Subject: RE: Climate inner loop on code that was distributed
> Importance: High
>
> Wow, this is the kind of analysis I was hoping for...is Preston a prof or?
>
> What is the 'Tera" machine?
>
> -----Original Message-----
> From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
> Sent: Tuesday, January 17, 2017 3:13 PM
> To: Oren Etzioni <orene@allenai.org>
> Cc: Ravi Jain <RaviJ@vulcan.com>; Paul Allen <Paul@vulcan.com>; Keith Rosema <KeithR@vulcan.com>; Spencer Reeder <SpencerR@vulcan.com>; Bill Hilf <BillH@vulcan.com>
> Subject: Re: Climate inner loop on code that was distributed
>
> Here's another very detailed response. I apologize for not having time today to organize these.
>
> ---------- Forwarded message ----------
> From: Preston Briggs <preston.briggs@gmail.com>
> Date: Tue, Jan 17, 2017 at 4:22 PM
> Subject: Re: Special request from Paul.
> To: Ed Lazowska <lazowska@cs.washington.edu>
> Cc: Carlo del Mundo <cdel@cs.washington.edu>
>
> Fortran, yum!
>
> In the old days, Kennedy and his students said "loop balance"
> instead of "operational intensity"; but it's a useful notion whatever the name.
> Unfortunately, it doesn't really speak to locality which is terrifically important.
>
> Starting at the top, I would rework the loops to improve things.

First, let's make it more readable

```
do j=js-1,je+1
  do i=is-1,ie
    ubt_Cor(i,j) = 0.0
  enddo
enddo

do j=js-1,je
  do i=is-1,ie+1
    vbt_Cor(i,j) = 0.0
  enddo
enddo

do j=js-1,je+1
  do k=1,nz
    do i=is-1,ie
      ubt_Cor(i,j) = ubt_Cor(i,j) + wt_u(i,j,k) * U_Cor(i,j,k)
    enddo
  enddo
enddo

do j=js-1,je
  do k=1,nz
    do i=is-1,ie+1
      vbt_Cor(i,j) = vbt_Cor(i,j) + wt_v(i,j,k) * V_Cor(i,j,k)
    enddo
  enddo
enddo
```

[looking at the original code, a loop nest using vbt_Cor has been omitted]

```
do j=js,je
  do i=is-1,ie
    Cor_ref_u(i,j) = ((amer(i-1,j) * ubt_Cor(i-1,j) + cmer(i  ,j+1) * ubt_Cor(i  ,j+1))
                  +  (bmer(i  ,j) * ubt_Cor(i  ,j) + dmer(i-1,j+1) *
ubt_Cor(i-1,j+1)))
  enddo
enddo
```

I'd say the code would run pretty well on a vector machine; indeed, it might have started life when vector machines were the norm.
To run well on a modern machine, we will probably have to do some reorganization.
Looking locally, at these loops only, not the rest of the program, I'd combine loops 1&3 and loops 2&4 and reorganize a bit, like this

```
do j=js-1,je+1
  do i=is-1,ie
    s = 0.0
    do k=1,nz
      s = s + wt_u(i,j,k) * U_Cor(i,j,k)
    enddo
```

```
    ubt_Cor(i,j) = s
  enddo
enddo

do j=js-1,je
  do i=is-1,ie+1
    s = 0.0
    do k=1,nz
      s = s + wt_v(i,j,k) * V_Cor(i,j,k)
    enddo
    vbt_Cor(i,j) = s
  enddo
enddo
```

Here the inner loops are dot products and execute approximately 1 flop per memory reference.
The win here is that s would be carried in a register across the inner loops.

I think it's more useful to think of memory refs instead of bytes, since everybody moves around (at least) 8 bytes at a time.

It might be more useful to think of it as one muladd for 2 mem refs, since many processors can do a multiply-accumulate in a single cycle.

So great, a big improvement over the original code (old was 1 muladd/4 refs).
and something that a sufficiently smart compiler could do.
(Kennedy's students wrote about it; Tera's compiler could certainly do it; I'm not sure about Cray's other compilers; I'm pessimistic about other modern compilers.)

But notice the accesses to wt_u, xt_v, U_Cor, and V_Cot.
They're all indexed (i,j,k), where the k index varies quickest.
In Fortran, this implies that each successive access to, say wt_u, has long stride and will provoke a cache miss (on most modern machines, though not the Tera). So a more useful summary of each loop nest is that it has a balance of 1 muladd per 2 cache misses.

On a distributed memory machine, when I say "cache miss", we are probably talking about a remote memory access. And looking at the pattern of references, we know there's no opportunity for re-use. That is, each time we fetch a value from a remote processor, we'll glance at it once and throw it away.

We might be able to improve matters by looking more globally and reorganizing the arrays so that we could rewrite the problem indices as (k,i,j). This would be wonderfully profitable here, but might be problematic in other places. Such a big change would likely be beyond any (?) compiler; typically the programmer would have to plan the global layout early in the design of the program (and the authors have probably done this; they're no dummies).

Let's consider the 5th loop, the stencil:

```
do j=js,je
  do i=is-1,ie
    Cor_ref_u(i,j) = ((amer(i-1,j) * ubt_Cor(i-1,j) + cmer(i  ,j+1) * ubt_Cor(i  ,j+1))
                   +  (bmer(i  ,j) * ubt_Cor(i  ,j) + dmer(i-1,j+1) *
ubt_Cor(i-1,j+1)))
  enddo
enddo
```

They've written it so the i index is innermost, which is great for reducing cache misses.
(we say all the arrays are accessed with a short stride, and we are able to re-use the cache lines so that several memory refs can be satisfied by a single cache miss).
Otherwise, there's no re-use of references to amer, bmer, cmer, and dmer, so no improvement is possible.
The refs to ubt_Cor are more interesting: there's reuse of values across both i and j iterations.
Here's it's possible (even easy) to rewrite the loop nest to hold many values of ubt_Cor in registers, thus avoid a number of memory references. The details wil depend on the target machine, but we can approach a loop balance of 1 muladd per ref, which sounds fine. But in terms of cache misses, we might see something like 2 muladds per cache miss (depending many details), which is not so great.

I mentioned above that the code would probably run well on a vector machine, approaching 100% utilization. That's because lots of the old iron had a "machine balance" of about 1 muladd per 3 memory references. A modern micro might be more like 1 muladd per memory reference. So the mis-match between loop balance and machine balance leads to relatively poor performance on modern processors.
And if cache misses are accounted for, the machine balance of a modern processor might be closer to 30 muladds per cache miss, or worse.

Of course, the modern processors (and GPUs, even more so) are much quicker than the old vector machines. But on a code like this, they'll spend their time mostly idle, waiting for cache misses and remote reads. So instead of the 100% utilization of the vector processors, we'll see 100% utilization of the memory system and some tiny fraction of a micro's potential flops.

Up to this point in the code, that's all I can see.
I think a modern micro or GPU would both be pretty underutilized, both waiting on cache misses, local and remote.
I don't see a way to recast the computation as a matrix multiply (which has plenty of reuse).

Same for the 2nd example computation (that I've ignored 'til now).
While it has control flow to uglify things, it's just a triply-nested loop organized so that all the references are stride one (good), but no other re-use, so no opportunity for improvement.

I expect I've written far too much.
Maybe there's something you can use,

Preston

On Tue, Jan 17, 2017 at 4:56 PM, Oren Etzioni <orene@allenai.org> wrote:
> Paul, Ed (cc'd) kindly pinged a bunch of folks with related expertise
> at CSE, and here are the most informative replies (with my highlights added).
>
> I read the answers as agreeing with Ravi.
>
>
>
> ---------- Forwarded message ----------
>
> From: Carlo C del Mundo <cdel@cs.washington.edu>
>
>

>
>
>
>
>
> The short answer is: no, GPU acceleration won't accelerate overall
> application performance by 10-100x. The overall application is memory
> bound, so adding GPUs into the mix won't help as much.
>
>
>
> The longer answer: for certain kernels, yes, you can theoretically
> achieve a 10x speedup using the GPU. The big caveat is: only for certain kernels.
> Since the application is a mixture of "high operational intensity" and
> "low operational intensity" operations, your overall speedup is
> limited by the slowest portion (Amdahl's Law).
>
>
>
> To address Paul's questions, you'll be bottlenecked by communication
> (e.g., data transfer to/from processors) rather than the computation.
>
> The primary reason is that for every byte that you have to process,
> you only compute a handful of operations (say 1 floating operation).
>
> Using a GPU won't help in this case because cores are idle waiting for
> data
> -- but increasing memory bandwidth will.
>
>
>
> GPUs fare very well for high operational intensity regimes (100s of
> floating point operations per byte). Matrix multiplication is one
> example, and sure, if the app below can be recast as matrix
> multiplication, you can benefit from significant acceleration using
> vendor-accelerated linear algebra libraries (about ~10x improvement
> over a tuned multi-core CPU implementation). That improvement is only
> relative to that particular function, and doesn't translate to overall application speedup.
>
>
>
>
>
> ---------- Forwarded message ----------
>
> From: Rastislav Bodik <bodik@cs.washington.edu>
>
>
>
>
>
> This is not a matrix computation and does not have the memory reuse
> pattern of one. Mark is right that one should not try to reduce the
> computation to a matrix library.

>
>
>
> Instead, the computation is a stencil, as Ravi points out. The
> vertical integral is a degenerate stencil, too.
>
>
>
> GPU streaming should work well for this code but it won't help
> operational intensity unless another level of tiling is introduced.
>
> Given the complexity of the ocean model, another level of tiling may
> be hard to engineer but HPC experts like Brad Chamberlain might be
> able to shed some light into whether this should be attempted.
>
>
>
> Since the Fortran code is already optimized, manually porting it to
> GPUs may be painful. A good compiler from stencils to GPUs would help
> in achieving these optimizations and one candidate compiler is of course Halide.
>
>
>
> I am cc-ing Alvin, who recently wrote a paper on porting Fortran
> stencil codes to Halide. Perhaps he can already alvinize this ocean modeling code?
>
>
>
> In the last paragraph, Ravi talks about accessing remote memory. A
> typical optimization for this big bottleneck in stencil codes are
> ghost cells but the Fortran code from Ravi seems to be doing it
> already under the name "wide halos". The good news is that Halide
> should be able to perform this optimization automatically (PPoPP 2016).
>
>
>
> I don't see an easy way around the if statements, by the way. But as
> Mark said, the divergence is not a big deal.
>
>
>
> To me, the key question is whether the port to GPUs will be worth it.
>
> The code will likely remain bandwidth limited so it might be
> preferrable to stay with the multi-level cache hierarchy of an SMP?
>
> Luis, Mark, what do you think?
>
>
>
> --Ras
>
>
>

>
>
> Halide:
> http://cgo.org/cgo2015/event/halide-code-generation-for-image-processi
> ng-and-stencil-computation-in-halide/
>
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>
> Alvin's stencil paper:
>
> https://homes.cs.washington.edu/~akcheung/papers/pldi16.pdf
>
>
>
> Ghost cells:
> http://ipcc.cs.uoregon.edu/lectures/lecture-8-stencil.pdf
>
>
>
> Halide PPoPP 2016:
> http://people.csail.mit.edu/tyler/papers/ppopp16.pdf
>
>
>
>

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Saturday, October 3, 2015 12:15 PM
To: Paul Allen
Cc: Oren Etzioni
Subject: Re: FW: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

I read the NY Times article with interest this morning, and sent a note to UW's Cliff Mass, who was quoted.

I would be happy to consult with my National Academy of Science climate modeling and weather modeling friends and get you an answer - I'll send off a few probes.

Cliff normally does a lot of whining about the lack of computational power, so I was pleased to see him acknowledge in the Times that it is not all about computational power: our models are behind, and our data assimilation techniques (the continuous incorporation of measurement data into simulation models as the models and reality both grind forward) are behind.

It doesn't matter what your grid size is (in your simulation) if you're not computing the right stuff, and if you're not correcting for observations as they become available!

In my view, we are seeing, in weather modeling, a repeat of the movie we saw 20 years ago in climate modeling. What my colleagues told me back then was that NCAR owns the US's "monopoly" climate model; NCAR scientists were slow to adapt their models to a scalable cluster computing environment, vs. vector machines; they spent all their time whining that they were forbidden from purchasing Japanese vector machines, which were faster than Crays; meanwhile the Europeans innovated in modeling approaches that were amenable to cost-effective scalable cluster computing, and passed us by.

My honest impression is that, relative to other nations, there is not a lot of innovation in weather and climate modeling in the US, because funding is concentrated - not enough competition.

I'll find out more - don't trust me on this because I'm out of date.

On Sat, Oct 3, 2015 at 12:01 PM, Paul Allen <Paul@vulcan.com> wrote:

> Your perspective?
>
> ---
>
> **From:** Spencer Reeder
> **Sent:** Saturday, October 3, 2015 11:58 AM
> **To:** Paul Allen <Paul@vulcan.com>
> **Cc:** Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>; Ravi Jain <RaviJ@vulcan.com>
> **Subject:** Re: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
>
> Hi Paul,
>
> Per your earlier question, "where is the best global warming modeling done?" There isn't a consensus answer to that question. Andy listed the top grant recipients in the U.S. and in my opinion the greatest accumulation of top U.S. talent resides at the National Center for Atmospheric Research (NCAR); however, there are a number of very good research groups spread around at different U.S. universities and federal labs (including PNNL here in Washington State).
>
> Also, internationally the Germans, the Brits, the Aussies, and Japanese all have very high quality modeling programs, with the Chinese seeking to enter the fray in a big way (see article below I sent Ravi earlier today).
>
> The question of which single group or model is "the best" is not how the climate science community has approached the overall modeling challenge however (though certainly individual models are evaluated and those that perform poorly are

not used). Researchers typically use what are called “multi-model ensembles” where they run models in parallel and where projections align, they assign higher confidence, and where they diverge, typically a lower confidence in the projection is assigned. One of most persistent challenges in climate modeling is accurately capturing cloud processes.

There are over 20 international modeling groups (using more than 30 different models) that collaborate under the auspices of the Coupled Model Intercomparison Project (CMIP). This effort started in 1995 and the 5th Phase of their work occurred from 2010 to 2014 in support of the most recent IPCC report.

Another thing that is done is that Global Climate Models (GCMs) are run backwards in time to see which perform best against historical climate observations; however, this has unfortunately not be a reliable predictor of future reliability. As the IPCC states, "there is still no universal strategy for weighting the projections from different models based on their historical performance.” There are metrics for evaluating individual models (primarily by perturbing various model parameters and generating reams of statistics) but most of the work is focused on ensembles of models as noted earlier. The model comparison work is an entire field of science in and unto itself (the IPCC has an entire chapter in their report dedicated to the topic).

My suggestion is that we confer with former colleagues of mine at NCAR and NOAA to see where the most significant gaps currently exist and report back to you.

GCMs are constantly evolving, adding more and more detailed physics (e.g., Biogeochemical processes, El Nino/La Nina influences) and there is a constant feedback between what the latest computing allows and the fidelity or complexity of what the researchers are trying to model from the earth system.

Regardless of the computing power however, if the physics aren't accurately captured, no amount of computing power will produce better results. The complexity of the latest vintage of GCMs may be starting to run up against the limits of our understanding of the complex geophysics and earth system interactions.

Spencer

From: Ravi Jain
Date: Saturday, October 3, 2015 at 10:41 AM
To: Paul Allen
Cc: Andy Hickl, Larry Felser, Spencer Reeder
Subject: RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

+Spencer

As it so happens, Spencer just sent me another article that describes China’s efforts to build a new supercomputer for doing ***climate*** modeling.

This may be a case of climate modeling being used to justify expenditures on a “Bigger Machine than Yours”, or it may be a real push into climate study. In either case, I believe Spencer has contacts at NCAR and elsewhere that we can use to get some opinion on this. (The level of investment China is talking about is not huge and within the realm of something we could contemplate I think, if it made sense.)

Ravi

From: Ravi Jain
Sent: Saturday, October 3, 2015 10:20 AM
To: Paul Allen <Paul@vulcan.com>
Cc: Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>
Subject: RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Ok, historically that is slightly different, at least as I understand it, although increasingly work is being done to relate them.

Ed would probably still be a good person to talk to.

But I think our internal Vulcan team dug into climate modeling and came up with the conclusions expressed in earlier emails.

On Oct 3, 2015 10:17, Paul Allen <Paul@vulcan.com> wrote:

> Well we are conflating two things...I was asking more about global warming modeling.....
>
> **From:** Ravi Jain
> **Sent:** Saturday, October 3, 2015 10:16 AM
> **To:** Paul Allen <Paul@vulcan.com>
> **Cc:** Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>
> **Subject:** RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
>
> This is weather modeling, correct, not climate modeling?
>
> A good place to start would be with the uw prof mentioned in the article. I talked to ed lazowska yesterday and we discussed meteorology as one of the application areas he is interested in and I think is represented in his data achieve center. I can reach out to him.
>
> I also have a couple of contacts at Stanford and Penn state if that fails.
>
> Ravi
>
> On Oct 3, 2015 10:11, Paul Allen <Paul@vulcan.com> wrote:
>
> > How could we figure out who has the best current code?
> >
> > **From:** Andy Hickl
> > **Sent:** Saturday, October 3, 2015 10:08 AM
> > **To:** Paul Allen <Paul@vulcan.com>; Ravi Jain <RaviJ@vulcan.com>
> > **Cc:** Larry Felser <LarryF@vulcan.com>
> > **Subject:** Re: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
> >
> > I haven't had time to dig in in detail, but spent a few minutes this morning throwing together a quick histogram of DOE grants over the past 25 years supporting work in (global) climate modeling: UCSD, UIUC, UW-Madison, and MIT are top grant-getters (other than the National Labs).

My (somewhat biased) contacts at DOE said that MIT, UCSD, UW-Madison, and Princeton are some of the best US schools, but the National Labs do most of the best work.

LAWRENCE BERKELEY NATIONAL LABORATORY	33
PACIFIC NORTHWEST NATIONAL LABORATORY	23
UCAR/NCAR	21
LOS ALAMOS NATIONAL LABORATORY	18
OAK RIDGE NATIONAL LABORATORY	14
CALIFORNIA, UNIV. OF SAN DIEGO	11
ILLINOIS, UNIV. OF URBANA-CHAM	11
UNIVERSITY OF WISCONSIN	11
MASSACHUSETTS INST. OF TECH.	11
COLORADO STATE UNIVERSITY	9
ARIZONA, UNIVERSITY OF	8
CALIFORNIA, UNIV. OF BERKELEY	8
CALIFORNIA, UNIV. OF LOS ANGEL	8
Harvard University	8
TEXAS A&M RESEARCH FOUNDATION	8
COLORADO, UNIVERSITY OF	7
MIAMI, UNIVERSITY OF	7
Naval Post Graduate School	7
IOWA STATE UNIVERSITY	6
OREGON STATE UNIVERSITY	6
PORTLAND STATE UNIVERSITY	6
WASHINGTON, UNIV OF, SEATTLE	6
ALASKA, UNIVERSITY OF	5
ARGONNE NATIONAL LABORATORY	5
ATMOSPHERIC & ENVIRONMENTAL RE	5
COLUMBIA UNIVERSITY	5
MARYLAND, UNIVERSITY OF	5
NOAA	5
PENNSYLVANIA STATE UNIVERSITY	5
Princeton University	5
Yale University	5
CALIFORNIA, UNIV. OF IRVINE	4
EAST ANGLIA, UNIVERSITY OF	4
NATIONAL SCIENCE FOUNDATION	4
NEW YORK, STATE U. OF ALBANY	4
NORTH CAROLINA STATE UNIVERSIT	4
Sandia National Laboratories	4
TEXAS, UNIVERSITY OF	4
DUKE UNIVERSITY	3

GEORGIA TECH RESEARCH CORP	3
HAWAII, UNIVERSITY OF	3
MARINE BIOLOGICAL LABORATORY	3
Michigan State University	3
MICHIGAN, UNIVERSITY OF	3
National Climatic Data Center	3
NEW YORK, STATE U. OF ST BROOK	3
PURDUE UNIVERSITY	3
RUTGERS - STATE UNIV OF NJ, NEW BRUNSWIC	3
University of Massachusetts	3
WISCONSIN, UNIVERSITY OF MILWAUKEE	3
WOODS HOLE OCEANOGRAPHIC INST.	3

Best,

Andy

--

Andy Hickl

Senior Director for Innovation, Vulcan, Inc.

Voice: (206) 342-2228 or (858) 366-8424

Web: http://andyhickl.com or @andyhickl

From: Paul Allen
Date: Saturday, October 3, 2015 at 9:03 AM
To: Andrew Hickl, Ravi Jain
Cc: Larry Felser
Subject: RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Jeez, where is the best global warming modeling done? Was that in one of the previous emails?

From: Andy Hickl
Sent: Saturday, October 3, 2015 9:03 AM
To: Ravi Jain <RaviJ@vulcan.com>; Paul Allen <Paul@vulcan.com>
Subject: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Interesting take on differences between U.S. and EU weather modeling which claims EU's superior hurricane forecasts stem from significantly more computing horsepower.

Not all the way to global climate models, of course -- but an interesting data point nonetheless.

Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
http://mobile.nytimes.com/2015/10/03/upshot/hurricane-joaquin-forecast-european-model-leads-pack-again.html?partner=rss&emc=rss&_r=0&referer=http://feedly.com/index.html
---

From: Paul Allen <Paul@vulcan.com>
Sent: Saturday, January 7, 2017 11:36 AM
To: lazowska@cs.washington.edu
Subject: FW: WaveScalar update

Neither of Oskin's projects seem to have taken off...any comment?

Paul

-----Original Message-----
From: Jim Boyden [mailto:jim@jboyden.com]
Sent: Monday, January 18, 2010 10:36 AM
To: Paul Allen <Paul@vulcan.com>
Subject: FW: WaveScalar update

I decided to forward to you all of Mark's response rather than interpret it since it goes beyond WaveScalar into something that may or may not be of interest.

-----Original Message-----
From: Mark Oskin [mailto:markoskin@gmail.com] On Behalf Of Mark Oskin
Sent: Monday, January 18, 2010 8:12 AM
To: Jim Boyden
Subject: Re: WaveScalar update

Hi Jim-

WaveScalar is paused until I return to academic life in the Fall of
2010 (8 months or so from now) I intend to pick it back up again.
I've been thinking about what a "version 2" microarchitecture would look like and I believe it'd have the following features (distinct from the original design):

- Aggressive memory alias speculation. Current systems are ~ 99% accurate on this, and I think coupling memory speculation with the out- of-order nature of execution WaveScalar has would be a big win performance wise.

- A tad more centralization. The original microarchitecture was too extreme in its thinking about distributed designs. What happened with silicon since 2001 was not what people thought. Instead, clock rate fell over because future processes are denser, butthe transistors are no faster. Hence, the need for such wide distribution of the microarchitecture is less. I wouldn't go all the way back to superscalar (which is very centralized), but I'd back away from the aggressive stance we took in "Version 1".

My current plan is to a sabbatical at UPC in 2010 - 2011 to work with Mateo and those guys to help refine the above two ideas. Then return to UW Fall of 2011 to start putting the team back together to research / build it.

As for Petra, we are still going strong. In fact, we are very close to getting our beta out the door. There's a nifty online demo Paul might be interested in watching at <http://petravm.com/jinx>. Our office is just across the Seahawks parking lot from Paul's office in fact, so if he'd like a demo of it in person I'm happy to walk over there and provide it. Here's one of our alpha customers and how they describe our product:

"As far as tools go, I have to say that for the type of work I do Jinx is kickin ass. I don't have much opportunity to use it at work (still not approved for install by IT (Edgar may be breaking the rules and using
it), but at home I've fixed several work issues by Jinx'ing the code)
In my
personal codebase it is really kickin ass since when used in unit tests it almost always catches any goof I may make in my highly threaded codebase.
With atomic ops I've managed to run 2-3 times without Jinx flagging something but it almost always catches it eventually. We're talking about a
1 in a million case for the most part, so damned good that it gets caught.
:)"

That paragraph comes from a guy who works for a major games development company.

Best wishes,

-Mark

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Sunday, October 16, 2016 7:43 PM

To: Paul Allen;Bert Kolde

Subject: Followup

Attachments: What is your dream?.pdf

Paul and Bert,

WHAT A GAME! (What a nail-biter!) Totally amazing! Thanks so much, Paul, for including me and Lyndsay.

I want you to know *exactly* what's going on with our building. Your generosity and your engagement and your willingness to help - over many years in many ways - are so important and so very much appreciated.

Amazon's commitment of $10 million is wonderful in two ways: it's a big plus for the project, and it represents a new level of civic engagement for the company.

Here comes *CONFIDENTIAL* part #1: Amazon's gift was a compromise that I've been working on for a year. I first spoke with them in October 2015. In February 2016 they offered $30 million to name the building for the company. The $30 million was workable: the UW Regents ultimately recognized that their stated target of $50 million was unrealistic. But naming for the company was not workable - it was simply not appropriate. We proposed every imaginable compromise: for example, name the building for Jeff, or for Ada Lovelace, or for Grace Murray Hopper, and we would "throw in" the highest profile internal space and name it for the company. But these were not appealing to the company, and in the end they committed $10 million to name an internal space.

We're extremely grateful for this gift, and we want Amazon to feel *great* about it and hope that they will support other community projects in this way in the future.

While I was going back and forth with Amazon (and as it was looking increasingly like they would only make a naming-level gift for the corporate name), I worked with Brad Smith, who's leading our campaign, on a Plan B. We were going to be left without a naming-level donor, so we were going to have to piece together sufficient funding to complete the project.

Here comes *CONFIDENTIAL* part #2 - only a handful of people know what follows. Brad's idea was to attempt to assemble a consortium of individuals who would band together to name the building for Bill Gates. We would have an Allen Center and a Gates Center. In the Gates Center would be a wall display that highlighted the two of you in a way that served as inspiration to future generations of students. The first-cut idea, from several months ago, is attached as a pdf.

Here's where it gets even more complicated. Of the $86 million that has been committed to the project, roughly $15 million is related to this concept. (And Brad and I have a number of solicitations related to the concept scheduled for November and early December, because in order to keep the project on schedule we must obtain pledges for essentially the entire cost of the project by the end of the calendar year.) If we abandon that concept, then we're probably at $71 million rather than $86 million. (Total project cost is $105M-$110M.)

(I hope it's OK with you that I'm being totally candid with you. There's just a bit more to go.)

I can see several paths forward:

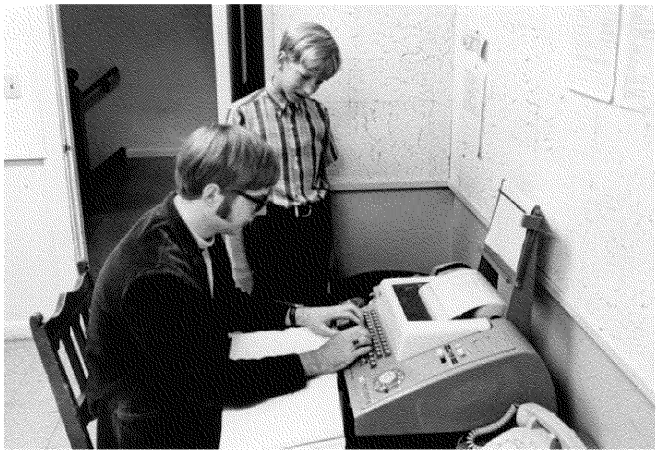
If you were willing to name the building for $30 million, we would instantly scrap the Gates plan. The project would be at $71M + $30M - $4M to $9M short of the total required, which would be a relatively easy gap to close. The UW Regents would green-light the start of construction (because the funding gap was negligible and the naming gift was at a level that they had already been persuaded was reasonable), and I would feel like I had died and gone to heaven. We would proudly have a Paul G. Allen Center for Computer Science & Engineering that spanned Stevens Way (or a CSE2 building named in some other way of your choosing) - a world-class home for what is on the brink of being truly a world-class computer science program.

If you were willing to provide $5M to $10M for the project to name a prominent interior space, we would complete the Gates plan (raising $30M from a consortium) and the funding would be complete. Your gift could either be part of the Gates naming, or independent of it. I'm going to be even more candid here: I have of course read Idea Man, and even before reading it I knew much of what was in it. For example, years ago (and years before the book) I nominated you for the National Academy of Engineering because I fully understood both your visionary contributions and your engineering contributions. In the fullness of time, through the lens of history, despite spats and slights, the two of you are going to be joined at the hip as two people who each changed the world multiple times in multiple ways, beginning with your partnership as teenagers in Seattle. A Gates Center and an Allen Center opposite one another on the UW campus would symbolize this magnificently.

The third possibility is that neither of these is appealing to you, in which case I'll grind ahead trying to get the project done (with Brad's amazing help), because making UW CSE a world-class program is what I've devoted my professional life to, and we're almost there.

And whatever you choose, I want to be sure you know how very deeply I appreciate your generosity to me, to UW, to our community, and to the world.

What is your dream?



Bill Gates and Paul Allen had a dream.

Their dream began at Lakeside School (where the Lakeside Mothers Club funded the acquisition of a teletype terminal), the University of Washington (where they roamed the halls using a variety of computers), and Computer Center Corporation (a UW spinoff company operating a PDP-10 timesharing service).

Their dream changed the world.

What is *your* dream? How can computer science help *you* change the world?

[I just made this up off the top of my head – nothing but an initial suggestion. Basic idea: A prominent wall display in the Atrium, with "What is your dream?" in raised lettering. Minimalist. Focus on Bill and Paul as inspirations to coming generations – attempting to be more comprehensive runs the risk of omitting key people, and the risk of being heavily male dominated. Would be accompanied by a plaque commemorating donors. These donors would also be recognized on the building donor wall, and would have named spaces if their gifts were at an appropriate level. There would also be a large touchscreen that allowed people to explore the history of tech in our region, and current research activities in CSE that had an "inspirational" character to them.]

From: Paul Allen <Paul@vulcan.com>
Sent: Saturday, October 3, 2015 12:02 PM
To: Oren Etzioni;Ed Lazowska
Subject: FW: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Your perspective?

From: Spencer Reeder
Sent: Saturday, October 3, 2015 11:58 AM
To: Paul Allen <Paul@vulcan.com>
Cc: Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>; Ravi Jain <RaviJ@vulcan.com>
Subject: Re: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Hi Paul,

Per your earlier question, "where is the best global warming modeling done?" There isn't a consensus answer to that question. Andy listed the top grant recipients in the U.S. and in my opinion the greatest accumulation of top U.S. talent resides at the National Center for Atmospheric Research (NCAR); however, there are a number of very good research groups spread around at different U.S. universities and federal labs (including PNNL here in Washington State).

Also, internationally the Germans, the Brits, the Aussies, and Japanese all have very high quality modeling programs, with the Chinese seeking to enter the fray in a big way (see article below I sent Ravi earlier today).

The question of which single group or model is "the best" is not how the climate science community has approached the overall modeling challenge however (though certainly individual models are evaluated and those that perform poorly are not used). Researchers typically use what are called "multi-model ensembles" where they run models in parallel and where projections align, they assign higher confidence, and where they diverge, typically a lower confidence in the projection is assigned. One of most persistent challenges in climate modeling is accurately capturing cloud processes.

There are over 20 international modeling groups (using more than 30 different models) that collaborate under the auspices of the Coupled Model Intercomparison Project (CMIP). This effort started in 1995 and the 5th Phase of their work occurred from 2010 to 2014 in support of the most recent IPCC report.

Another thing that is done is that Global Climate Models (GCMs) are run backwards in time to see which perform best against historical climate observations; however, this has unfortunately not be a reliable predictor of future reliability. As the IPCC states, "there is still no universal strategy for weighting the projections from different models based on their historical performance." There are metrics for evaluating individual models (primarily by perturbing various model parameters and generating reams of statistics) but most of the work is focused on ensembles of models as noted earlier. The model comparison work is an entire field of science in and unto itself (the IPCC has an entire chapter in their report dedicated to the topic).

My suggestion is that we confer with former colleagues of mine at NCAR and NOAA to see where the most significant gaps currently exist and report back to you.

GCMs are constantly evolving, adding more and more detailed physics (e.g., Biogeochemical processes, El Nino/La Nina influences) and there is a constant feedback between what the latest computing allows and the fidelity or complexity of what the researchers are trying to model from the earth system.

Regardless of the computing power however, if the physics aren't accurately captured, no amount of computing power will produce better results. The complexity of the latest vintage of GCMs may be starting to run up against the limits of our understanding of the complex geophysics and earth system interactions.

Spencer

From: Ravi Jain
Date: Saturday, October 3, 2015 at 10:41 AM
To: Paul Allen
Cc: Andy Hickl, Larry Felser, Spencer Reeder
Subject: RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

+Spencer

As it so happens, Spencer just sent me another article that describes China's efforts to build a new supercomputer for doing *__climate__* modeling.

This may be a case of climate modeling being used to justify expenditures on a "Bigger Machine than Yours", or it may be a real push into climate study. In either case, I believe Spencer has contacts at NCAR and elsewhere that we can use to get some opinion on this. (The level of investment China is talking about is not huge and within the realm of something we could contemplate I think, if it made sense.)

Ravi

From: Ravi Jain
Sent: Saturday, October 3, 2015 10:20 AM
To: Paul Allen <Paul@vulcan.com>
Cc: Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>
Subject: RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com

Ok, historically that is slightly different, at least as I understand it, although increasingly work is being done to relate them.

Ed would probably still be a good person to talk to.

But I think our internal Vulcan team dug into climate modeling and came up with the conclusions expressed in earlier emails.

On Oct 3, 2015 10:17, Paul Allen <Paul@vulcan.com> wrote:

> Well we are conflating two things...I was asking more about global warming modeling.....
>
> **From:** Ravi Jain
> **Sent:** Saturday, October 3, 2015 10:16 AM
> **To:** Paul Allen <Paul@vulcan.com>
> **Cc:** Andy Hickl <AndyH@vulcan.com>; Larry Felser <LarryF@vulcan.com>
> **Subject:** RE: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
>
> This is weather modeling, correct, not climate modeling?

A good place to start would be with the uw prof mentioned in the article. I talked to ed lazowska yesterday and we discussed meteorology as one of the application areas he is interested in and I think is represented in his data achieve center. I can reach out to him.

I also have a couple of contacts at Stanford and Penn state if that fails.

Ravi

On Oct 3, 2015 10:11, Paul Allen <Paul@vulcan.com> wrote:

> How could we figure out who has the best current code?
>
> ---
>
> **From:** Andy Hickl
> **Sent:** Saturday, October 3, 2015 10:08 AM
> **To:** Paul Allen <Paul@vulcan.com>; Ravi Jain <RaviJ@vulcan.com>
> **Cc:** Larry Felser <LarryF@vulcan.com>
> **Subject:** Re: Hurricane Joaquin Forecast: Why U.S. Weather Model Has Fallen Behind - NYTimes.com
>
> I haven't had time to dig in in detail, but spent a few minutes this morning throwing together a quick histogram of DOE grants over the past 25 years supporting work in (global) climate modeling: UCSD, UIUC, UW-Madison, and MIT are top grant-getters (other than the National Labs).
>
> My (somewhat biased) contacts at DOE said that MIT, UCSD, UW-Madison, and Princeton are some of the best US schools, but the National Labs do most of the best work.

LAWRENCE BERKELEY NATIONAL LABORATORY	33
PACIFIC NORTHWEST NATIONAL LABORATORY	23
UCAR/NCAR	21
LOS ALAMOS NATIONAL LABORATORY	18
OAK RIDGE NATIONAL LABORATORY	14
CALIFORNIA, UNIV. OF SAN DIEGO	11
ILLINOIS, UNIV. OF URBANA-CHAM	11
UNIVERSITY OF WISCONSIN	11
MASSACHUSETTS INST. OF TECH.	11
COLORADO STATE UNIVERSITY	9
ARIZONA, UNIVERSITY OF	8
CALIFORNIA, UNIV. OF BERKELEY	8
CALIFORNIA, UNIV. OF LOS ANGEL	8
Harvard University	8
TEXAS A&M RESEARCH FOUNDATION	8
COLORADO, UNIVERSITY OF	7
MIAMI, UNIVERSITY OF	7

Naval Post Graduate School	7
IOWA STATE UNIVERSITY	6
OREGON STATE UNIVERSITY	6
PORTLAND STATE UNIVERSITY	6
WASHINGTON, UNIV OF, SEATTLE	6
ALASKA, UNIVERSITY OF	5
ARGONNE NATIONAL LABORATORY	5
ATMOSPHERIC & ENVIRONMENTAL RE	5
COLUMBIA UNIVERSITY	5
MARYLAND, UNIVERSITY OF	5
NOAA	5
PENNSYLVANIA STATE UNIVERSITY	5
Princeton University	5
Yale University	5
CALIFORNIA, UNIV. OF IRVINE	4
EAST ANGLIA, UNIVERSITY OF	4
NATIONAL SCIENCE FOUNDATION	4
NEW YORK, STATE U. OF ALBANY	4
NORTH CAROLINA STATE UNIVERSIT	4
Sandia National Laboratories	4
TEXAS, UNIVERSITY OF	4
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Best,

Andy

--

Andy Hickl

Senior Director for Innovation, Vulcan, Inc.

Voice: (206) 342-2228 or (858) 366-8424

Web: http://andyhickl.com or @andyhickl

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---

From: Paul Allen <Paul@vulcan.com>
Sent: Monday, September 5, 2016 3:01 AM
To: lazowska@cs.washington.edu;Tom Daniel
Cc: Keith Rosema;Ravi Jain
Subject: FW: Friday Harbor Lab Summer Course

Just FYI...Paul

From: Christof Koch [mailto:ChristofK@alleninstitute.org]
Sent: Sunday, September 4, 2016 10:26 PM
To: Paul Allen <Paul@vulcan.com>; Allan Jones (AIBS) <AllanJ@alleninstitute.org>
Subject: Friday Harbor Lab Summer Course

Hi Paul and Allen,

We just finished our two week long very intensive, summer course "The Dynamic Brain" at UW's Friday harbor Laboratory on San Juan Island. The 24 students (senior graduate students and post-docs, supported by 12 faculty and staff) really took to the "Allen Brain Observatory" data set to our jupyter notebooks like fish to water.

Their projects were among the best I've seen in 25 years of teaching 'computational neuroscience' summer courses.

We'll try to continue to work with some of them (last year, a paper was published based on one a summer course project).

See our short blog with some photos here

http://compneuro.washington.edu/the-dynamic-brain/

Christof

--
Dr. Christof Koch
President and *Chief Scientific Officer*

ALLEN INSTITUTE for BRAIN SCIENCE

Allen Institute for Brain Science, Seattle

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Wednesday, April 8, 2015 9:52 AM

To: Paul Allen

Subject: A quick CSE2 update

Attachments: Pages from scBillEHB1115_0408.pdf

Paul,

You asked me to keep you updated on the CSE2 project. This is a legislative update. There is a lot of sausage yet to be made, but we are headed in the right direction:

UW had sought $40M from the state to get the CSE2 project launched.

The Governor put the $40M in his budget.

The House capital budget only included $6M - the design fee, but no funding for construction.

The Senate capital budget is just out. It has $32.5M, plus specific language related to the use of the preferred site. So we are heading in the right direction!

Microsoft (DeLee Shoemaker), WTIA (Michael Schutzler), and UW (Genesee Adkins) were incredibly important in overcoming the setback in the House. Now we have to make it stick.

Health Sciences Interprofessional Education Classroom Phase I (30000602)

Appropriation:

State Building Construction Account—State. $2,710,000

Prior Biennia (Expenditures). $0

Future Biennia (Projected Costs). $0

TOTAL. $2,710,000

NEW SECTION. **Sec. 5042. FOR THE UNIVERSITY OF WASHINGTON**

Computer Science and Engineering Expansion (30000603)

The appropriation in this section is subject to the following condition and limitation: The appropriation is provided solely for the construction of a new computer science and engineering building built in a location consistent with the preferred site as recommended by the CSE II feasibility study produced by LMN architects and analyzed in the 2015 environmental impact study.

Appropriation:

State Building Construction Account—State. $32,500,000

Prior Biennia (Expenditures). $0

Future Biennia (Projected Costs). $0

TOTAL. $32,500,000

NEW SECTION. **Sec. 5043. FOR THE UNIVERSITY OF WASHINGTON**

University of Washington Minor Capital Repairs - Preservation (30000604)

Appropriation:

University of Washington Building Account—State. . . $43,175,000

Prior Biennia (Expenditures). $0

Future Biennia (Projected Costs). $172,700,000

TOTAL. $215,875,000

NEW SECTION. **Sec. 5044. FOR THE UNIVERSITY OF WASHINGTON**

Minor Capital Repairs - Preservation (30000494)

Reappropriation:

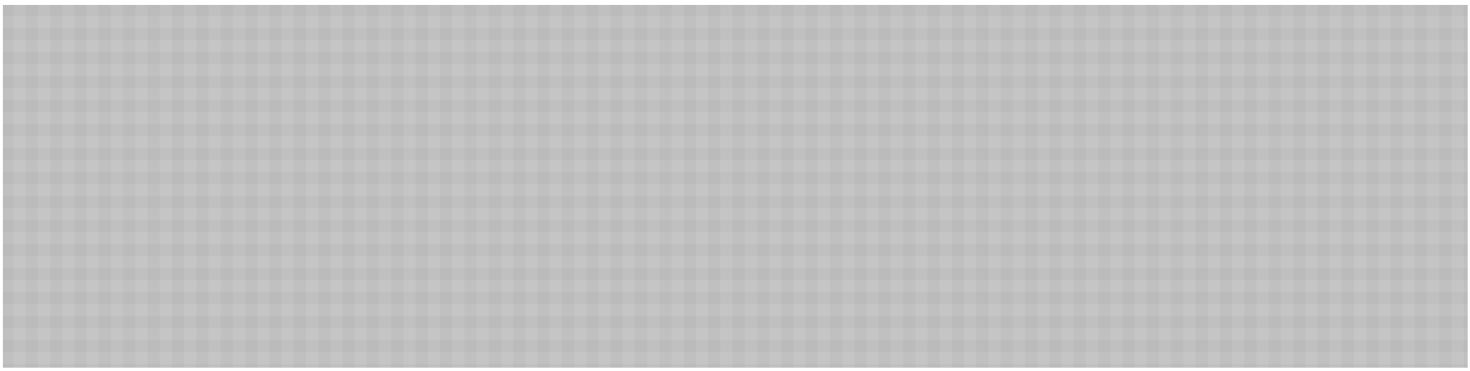
University of Washington Building Account—State. . . . $4,200,000

Prior Biennia (Expenditures). $42,554,000

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, March 31, 2015 9:15 PM
To: Paul Allen
Cc: Tom Daniel (danielt@uw.edu);Tom Skalak;Keith Rosema;Andy Hickl;Allan Jones (AIBS);Christof Koch (koch.christof@gmail.com)
Subject: Re: Future initiatives in CSEE and Biology
Attachments: Mercury.pdf; 100K summary.docx

Paul,

6 weeks ago you inquired about possible initiatives at the biology/cs interface.



I feel that the potential for this is huge - truly transformational. Lee and his younger colleague Nathan Price have an extraordinary vision. What's most exciting to me is that there are measurable, actionable outcomes along the road to the long-term transformation of the disease industry to the wellness industry: it's not a matter of "work at this for ten years and then you'll see results" - there are intermediate benefits all along the way.

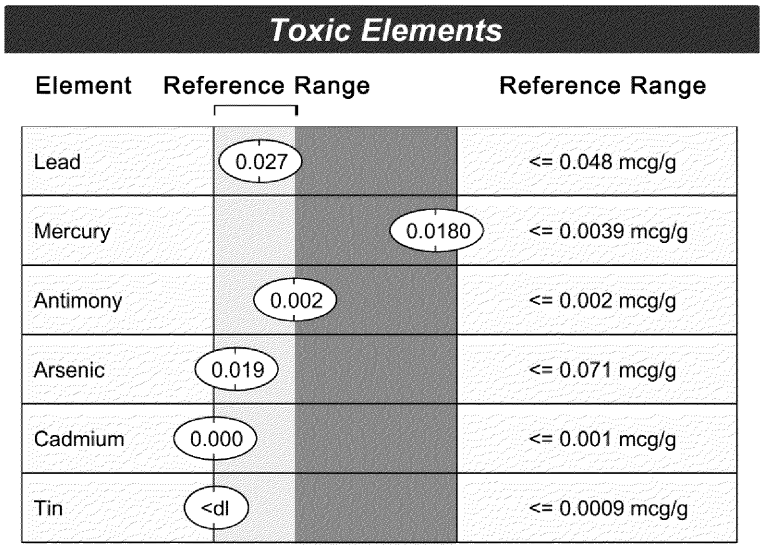
I asked Lee and Nathan to provide a short description (without telling them why). It's attached.

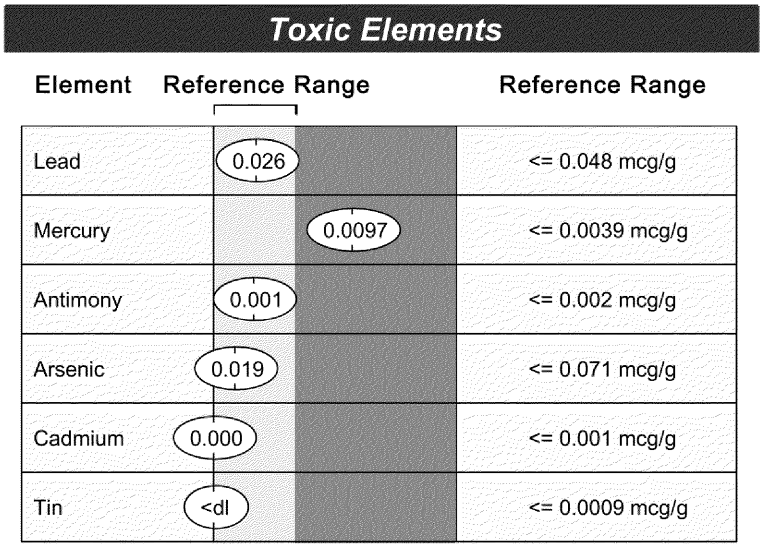
I've been truly excited by this.

On Mon, Feb 9, 2015 at 10:29 AM, Paul Allen <Paul@vulcan.com> wrote:

> What do you see as the larger scale "needle mover" initiatives or explorations in those fields that should be pumped up or done in a more industrial or large scale way?
>
> What are the insufficiently explored frontiers?
>
> I feel I should re-ask these questions from time to time.
>
> Thanks,
> Paul

Only change: 8 weeks of having salmon sushi vs. tuna sushi (roughly 3X per week)





Vision and Implementation of The 100K Person Wellness Project

Leroy Hood and Nathan Price

The Institute for Systems Biology in Seattle is leading a transformation in healthcare that is driven by a systems approach to disease (systems medicine) and the application of big data to the analysis of individuals. Systems medicine has two central features: the creation of dynamical, multi-dimensional omic and physiological data clouds for each individual, and the ability to translate these data clouds into an identification of the biological networks that mediate the information of human development, physiology and aging. When disease-perturbed networks are analyzed, their differences from normal networks reveal insights into disease mechanisms, and from these emerge early diagnostics and new approaches to therapy. Systems medicine is at a tipping point because of the emergence of new technologies and strategies for dealing with disease—and this has led to the insight that healthcare must be predictive, preventive, personalized and participatory—or P4 medicine.

P4 medicine suggests that medicine can predict and prevent disease for the individual. It suggests that disease must be personalized—based on an analysis of the individual. It envisions that each individual will participate directly and thoughtfully in managing his or her own health.

P4 medicine has two central thrusts: quantifying wellness and demystifying disease. The current healthcare industry focuses 98% of their efforts and resources on dealing with disease. P4 medicine will enable the quantification of wellness and thus will drive the creation of a new scientific wellness industry that we predict will, in 10-15 years, far exceed the market cap of the current healthcare industry–the disease industry. The center of this new scientific wellness industry could emerge in Seattle. The scientific wellness industry will allow us to optimize human potential through scientifically increasing wellness for each individual and it will transform the disease industry by delineating the earliest wellness-to-disease transitions for all common diseases so that the earliest disease mechanisms may be understood—leading to powerful early diagnostics and new therapies. These insights will allow diseased individuals to be restored to wellness at the earliest time points—saving the healthcare system billions of dollars in dealing with unnecessary disease. Central to this approach is the generation of the data needed to provide a “search engine for the human body.” Furthermore, this new approach seeks not only the absence of disease but to optimize each individual’s wellness so as to maximize their human potential and allow them to enhance their healthy lifespan and the joyful moments that they get to experience.

This is a bold vision of the future and a striking opportunity, but what makes it really exciting is that it is now, for the first time, possible the envision how to create such a future and begin building the scientific wellness industry now.

One of the most exciting on-going wellness projects is located here in Seattle and is led by Lee Hood, who has pioneered systems approaches to biology and medicine from its very inception and who has been the leading voice in the world on a P4 Medicine that is personalized, predictive, preventive, and participatory. Lee Hood along with his colleague Nathan Price, a computational biologist, have recently launched an ambitious project to make concrete this vision and with the potential to put Seattle as the epicenter of this new scientific wellness industry. They call this project the 100,000 person wellness project, or “100K project” and have also founded a scientific wellness company to take this approach to a broad range of individuals.

The basic idea of the 100K project is to gather a large amount of longitudinal, multidimensional omic and physiological data from the 100,000 people in order to 1) to define metrics for a scientific wellness that will move provide it with a scientific underpinning, 2) enable the data for each individual to be integrated and modeled so as to identify “actionable possibilities” which if acted up will allow individuals to optimize their wellness and/or avoid or ameliorate disease; and 3) identify the early wellness to disease transitions for all major diseases. This approach will generate for each individual virtual and dynamical clouds of billions of data points that will provide unique and personalize insights into the wellness and disease of each individual.

This is an idea whose time has come and the group at ISB has operationalized this approach over the past year, taking a set of 107 individuals through this program (including for each individual complete genome sequences, quantized self measurements and every 3 months clinical chemistries, metabolites, proteomes, and gut microbiome analyses). The results of this Pioneer 100 study have been spectacular. All the Pioneers had actionable items to optimize their health, including the identification of unknown and potentially life-threatening diseases (and successful treatment through the medical system), a 33% reduction in pre-diabetes, the identification of toxins reduced or eliminated through behavior change, and the identification of completely new dimensions of data space interrelating genetics, microbiome, proteomics, metabolomics, wearable devices and so forth. We can now predict for each individual his or her genetic predispositions to more than 50 common diseases. Importantly, the project engaged wellness coaches to help explain the actionable possibilities for each individual and persuade them to act based on their own health goals (70% of the actionable possibilities were acted upon—emphasizing the incredible important of coaching behavioral modification). The immediate effect for participants is the spark to ignite long-term engagement, which is critical to building the back-end database that will drive disease-transition and wellness discovery. Mining the resulting big data is the key to crossing the bridge from ignorance to knowledge on the transition states between wellness and disease with enough molecular detail to design strategies for preventive interventions.

Taken together, the convergence of computer science, big data and systems biology (medicine) enables this new type of proactive medicine long envisioned by Lee Hood that is personalized, predictive, preventive, and participatory (P4). Key attributes of this approach include: (1) it is proactive, not reactive; (2) it focuses on the individual rather than population statistics; (3) it places a major focus on wellness and not just disease; (4) it generates dynamical individual data clouds that can be used to optimize wellness and eliminate disease; and (5) it empowers individuals to participate in their own health. This P4 concept is now ready for broad implementation and has been brought to a level of operational maturity now that needs capital to supercharge. It also provides a unique opportunity to create the new scientific wellness industry and use industrial-academic strategic partnerships to drive this scientific wellness vision forward effectively. This is a really big opportunity and this is now ready to be really acted upon for the first time in an industrial and large-scale way.

From: Oren Etzioni <orene@allenai.org>
Sent: Thursday, March 23, 2017 2:53 PM
To: Ed Lazowska;Paul Allen;Allen Israel;Bert Kolde;Paul Gilbert;Dave Stewart
Subject: RE: The exterior banner is up!

Awesome!

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Thursday, March 23, 2017 2:35 PM
To: Paul Allen <paul@vulcan.com>; Allen Israel <allen.israel@foster.com>; Bert Kolde <BertK@vulcan.com>; Paul Gilbert <gilbpj@gmail.com>; Dave Stewart <DaveS@vulcan.com>; Oren Etzioni <OrenE@allenai.org>
Subject: The exterior banner is up!

At last, we are fully decked out!

(And the first pledge payment arrived, too! THANK YOU PAUL!)

From: Paul Allen <Paul@vulcan.com>
Sent: Thursday, March 9, 2017 2:19 PM
To: lazowska@cs.washington.edu;Steve Lombardi;John Pinette
Subject: Re: Done!

Great!!

----- Original Message -----
From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Thursday, March 09, 2017 02:10 PM
To: Paul Allen; Steve Lombardi
Subject: Done!

2:09 p.m. and we are REAL!

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, March 17, 2017 9:11 PM
To: Paul Allen
Subject: Fwd: You are invited to a special event at Living Computers Museum
Attachments: signature.asc

I think I bullied Woz into attending!

---------- Forwarded message ----------
From: ʞɐıuzoʍ əʌəʇs <steve@woz.org>
Date: Fri, Mar 17, 2017 at 9:06 PM
Subject: Re: You are invited to a special event at Living Computers Museum
To: Ed Lazowska <lazowska@cs.washington.edu>
Cc: j Wozniak <janet@woz.org>

We'll be attending.

I love the hands-on approach. All of these machines were standouts in my life.

I wonder if the museum has a Symbolics lisp machine? It didn't go anywhere but always stood out in my mind.

best,
Woz

> On Mar 17, 2017, at 8:53 PM, Ed Lazowska <lazowska@cs.washington.edu> wrote:
>
> It would be phenomenal if you could make it. First of all, these are
> your machines. Second, the LCM is really wonderful. Everything works,
> and you can sit down and use everything. In addition to this new
> complete Apple exhibit, there's every PC running the period OS and
> period games; PDP-10; DEC 20; CDC 6500; Xerox Alto; SDS Sigma; all up
> and running.
>
> We refer to the Computer History Museum as the "dead computer museum."
> Paul's Living Computer Museum is the antithesis - it's all there, it's
> all running, you can sit down and use everything.
>
> Hope you can make it, Woz!!
>
> On Fri, Mar 17, 2017 at 8:44 PM, ʞɐıuzoʍ əʌəʇs <steve@woz.org> wrote:
>> I can't guarantee my attendance for multiple reasons, but I have put a reminder on my calendar, just in case. Right now I'm not blocked, schedule-wise. Obviously, this is something that I fit very well.
>>
>> best,
>> Woz
>>
>>> On Mar 17, 2017, at 6:45 PM, Ed Lazowska <lazowska@cs.washington.edu> wrote:
>>>
>>> Woz,
>>>
>>> You should come to this!!!!!

>>>
>>> The Living Computer Museum is phenomenal, and this will be a special night.
>>>
>>> Can you make it???
>>>
>>>
>>> ---------- Forwarded message ----------
>>> From: Lath Carlson <LathC@livingcomputers.org>
>>> Date: Fri, Mar 17, 2017 at 6:24 PM
>>> Subject: You are invited to a special event at Living Computers
>>> Museum
>>> To: "lazowska@cs.washington.edu" <lazowska@cs.washington.edu>
>>>
>>>
>>> Hi Ed,
>>>
>>>
>>>
>>> Living Computers: Museum + Labs, would like to invite you to a very
>>> special private event.
>>>
>>>
>>>
>>> We are celebrating the opening of our latest exhibit, which follows
>>> the first 20 years of Apple Computers, by throwing a party for those
>>> who were there. This is a unique opportunity to reconnect to the
>>> people, and computers, that you remember from the start of the
>>> personal computer revolution.
>>>
>>>
>>>
>>> Use working computers from the Apple 1 to the iMac, and even a
>>> NeXTcube. These publicly operable computers join our collection of
>>> working machines like the CDC-6500, DEC PDP-7,8,8e,10,11,12, IBM
>>> 360/20, Sigma 9, XEROX Alto, Altair, and so many more.
>>>
>>>
>>>
>>> Please see attached invitation for details, and RSVP to
>>> events@livingcomputers.org<mailto:events@livingcomputers.org>
>>>
>>>
>>>
>>> This is a private event, but if you have someone you think should be
>>> invited, please let me know directly.
>>>
>>>
>>>
>>> We look forward to seeing you here!
>>>
>>>
>>>
>>> Lāth Carlson

>>>
>>> Executive Director | Living Computers: Museum + Labs
>>>
>>> D 206.342.2166 | M 206.459.2213
>>>
>>> Living Computers<http://www.livingcomputers.org/>
>>
>>
>> ʞɐıuzoʍ ǝʌǝʇs
>> steve@woz.org
>>
>> It doesn't work that way
>> -- Ariana Gillis, John and the Monster
>>
>> PGP (GPG) fingerprint 5796 CED6 9AC6 7EC1 B42B 56CB 7933 8524 A90B
>> B342
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>>

ʞɐıuzoʍ ǝʌǝʇs
steve@woz.org

It doesn't work that way
-- Ariana Gillis, John and the Monster

PGP (GPG) fingerprint 5796 CED6 9AC6 7EC1 B42B 56CB 7933 8524 A90B B342

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, March 14, 2017 9:44 AM
To: Steve Lombardi;Paul Allen;Bill Ayer;Joel Benoliel;Mike Bragg;Ana M. CAUCE;Tom Daniel;Paul Gilbert;Allen Israel;Jeremy Jaech;Bert Kolde;Connie Kravas;Ed Lazowska;Hank Levy;Judy Mahoney;Constance Rice;Franzi Roesner;Pat Shanahan;Rob Short;B Silverberg;Herb Simon;Charles Simonyi;Ben Slivka;Dave Stewart;Brad Smith;Austin Michael Wright-Pettibone;pamayer50@gmail.com;moebenoliel7@gmail.com;Jacquelyn Jaech;Alison Kolde;K. Kravas;Lyndsay Downs;rkatz@Nephrology.washington.edu;Norm Rice;Emer Dooley;Lisa Simonyi
Subject: Fwd: Reception Photos

Photos from Thursday evening's Paul G. Allen School celebratory reception.

---------- Forwarded message ----------
From: **Peta Dyken** <petad@uw.edu>
Date: Tue, Mar 14, 2017 at 9:24 AM
Subject: Reception Photos
To: "JUDY K. MAHONEY" <jkm7@uw.edu>, Ed Lazowska <lazowska@cs.washington.edu>
Cc: Karine Raetzloff <kariner@uw.edu>, Annie Alldredge <alldra@uw.edu>

Good morning,
The photos from the Hill-Crest reception are now uploaded and available for viewing using the following link:

http://client.tara-brown.com/uwpaulgallenreception/

To log in, guests enter their email address and click through.
Please feel free to share/forward on to guests or others you feel are appropriate.

Best,
Peta D.

PETA DYKEN
President's Residence, Events

UW Tower Box 359520
4333 Brooklyn Avenue NE, S-4 Seattle, WA 98195-9520
206.685.6337 / mobile 206.310.4080
petad@uw.edu / washington.edu

UNIVERSITY of WASHINGTON

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Friday, March 10, 2017 7:22 AM

To: Bert Kolde;Allen Israel;Paul Allen;Ana M. CAUCE;Pat Shanahan;Brad Smith

Subject: Pretty good placement in the Seattle Times!

(And I'm glad we sprung for those t-shirt cannons!)

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, March 10, 2017 7:26 AM
To: Paul Allen
Subject: Re: Pretty good placement in the Seattle Times!

The students hanging from the rafters were AMAZING.

And the fact that the entire event was forward-looking. This will change a lot of lives!!!!!

THANK YOU PAUL!

On Fri, Mar 10, 2017 at 7:24 AM, Paul Allen <Paul@vulcan.com> wrote:

> That's Great!
> I couldn't ask for more from yesterday's event...what a great reception, and again I'm so glad to have been able to help the school!
> Paul
>
> **From:** Ed Lazowska [mailto:lazowska@cs.washington.edu]
> **Sent:** Friday, March 10, 2017 7:22 AM
> **To:** Bert Kolde <BertK@vulcan.com>; Allen Israel <allen.israel@foster.com>; Paul Allen <Paul@vulcan.com>; cauce@uw.edu; Pat Shanahan <patrick.m.shanahan@boeing.com>; Brad Smith <bradsmi@microsoft.com>
> **Subject:** Pretty good placement in the Seattle Times!
>
> (And I'm glad we sprung for those t-shirt cannons!)
>
> 
> 'RONG' IS ALL FURY
> The Seattle Times
> 'Game-changer': Allen gives UW $40M to create school
> Latest ban falls under old order, AG says

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Thursday, March 23, 2017 2:35 PM

To: Paul Allen;Allen Israel;Bert Kolde;Paul Gilbert;Dave Stewart;Oren Etzioni

Subject: The exterior banner is up!

At last, we are fully decked out!

(And the first pledge payment arrived, too! THANK YOU PAUL!)

From: Paul Allen <Paul@vulcan.com>

Sent: Wednesday, March 29, 2017 11:25 AM

To: lazowska@cs.washington.edu

Subject: FW: Framed letter to Dr. Golde

Let me know if you want another copy!

-----Original Message-----
From: Marilyn Valentine
Sent: Wednesday, March 29, 2017 7:23 PM
To: Paul Allen <Paul@vulcan.com>
Subject: Framed letter to Dr. Golde

This is being sent to Dr. Golde today via courier. It turned out great! We had a high quality copy made that shows the wrinkles and folds. It looks really good in the frame.

UNIVERSITY OF WASHINGTON

[illegible]

[illegible], 197[illegible]

Mr. Paul Allen
[illegible]
Seattle, Washington

Dear Mr. Allen:

I regret to have to write this letter to you and your friends from the Lakeside School, but the needs of the Computer Science Program leave me with no other alternative.

During the past months, you and your friends have been using the facilities of the Computer Science Laboratory to develop a software product for a [illegible] in Portland. While I am [illegible] with such activities, your use of the laboratory facilities has caused a number of complaints and tends to disrupt the intended use of the laboratory. To be more specific, let me give a number of specifics:

1. You have used the teletype for close to [illegible] for prolonged periods of time, and [illegible] to produce [illegible] listings. This use creates a noise level in the laboratory which is detrimental to the normal activities and also [illegible] the intended mode of operation for a remote console.

2. You have used the IMLAC system to connect to the [illegible] system [illegible] checked up this device. While you and some of your friends subsequently received a [illegible] license for the IMLAC, I have [illegible] that your friends did not get a [illegible] license for the [illegible], which was clearly announced to be a prerequisite.

3. Earlier this week, you removed the [illegible] from Dr. [illegible]'s office without authorization and without leaving at least a note. Such behavior is intolerable in any environment.

In view of these and other [illegible] which caused a number of complaints from the regular users of the laboratory, I must ask you to turn in your keys and terminate your activities in the laboratory immediately. Please inform your friends of this letter.

Sincerely,

[signature]

Hellmut Golde
Director, Computer Science Laboratory

HG:[illegible]

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Thursday, May 4, 2017 11:34 AM
To: Paul Allen
Subject: Progress!

Paul,

As of today we have a tower crane across the street from the Allen Center - photo attached.

And individuals are making pledges to augment the Allen School Endowment - Oren and Ivone Etzioni pledged $100,000 yesterday. This is really wonderful!

And AI2 once again showed great progress at the meeting yesterday - not sure if you were tuned in from London or not.

And there was a lovely editorial in today's Seattle Times, which undoubtedly you've seen, but just in case: http://www.seattletimes.com/opinion/editorials/cheers-to-deep-pocket-boosters-of-housing-and-education/

Hope you're well. And THANK YOU!

From: Paul Allen <Paul@vulcan.com>
Sent: Friday, March 10, 2017 7:24 AM
To: lazowska@cs.washington.edu
Subject: RE: Pretty good placement in the Seattle Times!

That's Great!
I couldn't ask for more from yesterday's event...what a great reception, and again I'm so glad to have been able to help the school!
Paul

From: Ed Lazowska [mailto:lazowska@cs.washington.edu]
Sent: Friday, March 10, 2017 7:22 AM
To: Bert Kolde <BertK@vulcan.com>; Allen Israel <allen.israel@foster.com>; Paul Allen <Paul@vulcan.com>; cauce@uw.edu; Pat Shanahan <patrick.m.shanahan@boeing.com>; Brad Smith <bradsmi@microsoft.com>
Subject: Pretty good placement in the Seattle Times!

(And I'm glad we sprung for those t-shirt cannons!)

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, April 14, 2017 9:56 PM
To: Paul Allen
Subject: Fwd: Photos from Homebrew/Apple Reunion
Attachments: Group with Labels.jpg; Full Group sm.jpg; Apple Group with Labels V2.pdf

You look SO HAPPY in these photos!!!!!

---------- Forwarded message ----------
From: Lath Carlson <LathC@livingcomputers.org>
Date: Fri, Apr 14, 2017 at 4:49 PM
Subject: Photos from Homebrew/Apple Reunion
To:
Cc: Matisse Fletcher <MatisseF@livingcomputers.org>

Thank you all so much for coming to our event on Wednesday!

I hope you had a great time and were able to reconnect with some old friends, and computers. I know our staff here, and our founder, very much enjoyed the night.

Pictures from the event can be found here:
https://www.flickr.com/gp/148538213@N08/8Fp890

We are posting these for your personal use, although you can share a few on social media if you like. Any use beyond that would need to be cleared with us. If you are able to credit the photographer, he is Dario Impini.

Best regards,
Lath

Lāth Carlson
Executive Director | Living Computers: Museum + Labs D 206.342.2166 | M 206.459.2213 Living Computers<http://www.livingcomputers.org/>

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, March 31, 2015 9:44 PM
To: Paul Allen;Tom Daniel;Tom Skalak;Keith Rosema;Andy Hickl;Allan Jones;Christof Koch
Subject: Fwd: Material for tomorrow's phone call
Attachments: Input from Ed Lazowska.docx; This decade.pdf; Modern view of CS.pdf

Here is some material I sent to the President's Council of Advisors on Science and Technology in advance of a teleconference tomorrow regarding CS-specific research challenges.

There is not much detail in the attachments. But let me describe just one of them in a bit more depth. There is a potential to achieve 10**6 greater digital storage density using DNA. The access latency is crappy - 30 minutes until you see the first bit. But the bandwidth is huge - it's arbitrarily parallelizable (or however you spell it). My UW CSE colleague Luis Ceze, who is an idea machine, is pursuing this - "a sequencer with a USB port." The interface between CS and biology is unbelievably rich.

---------- Forwarded message ----------
From: **Ed Lazowska** <lazowska@cs.washington.edu>
Date: Mon, Mar 30, 2015 at 8:58 PM
Subject: Material for tomorrow's phone call
To: Susan Graham <graham@cs.berkeley.edu>, Greg Hager <hager@cs.jhu.edu>

3 files attached.

Input from Ed Lazowska (with help from his friends)

A view of the current decade – stated in 2010 but with more recent examples

See attached pdf.

A modern view of computer science

See attached pdf

Some newer topics

- Nature Inspired Computing
  Living systems acquire, process and store information with vastly greater efficiency than synthetic systems. While silicon provides the platform for the planet's most rapid and precise computations, living systems compute with the planet's least cost per instruction. Today we have technologies that might allow us to harness the ideas and physics of living systems: new approaches in systems neuroscience, cell culture, synthetic biology, computing architecture, and device technology (electrodes and optogenetics) may permit novel computing architectures and approaches. If we can learn from and emulate natural computing we have a chance of pushing Moore's Law into a new trajectory (with respect to energy).

- Mobile Health Innovation
  There are very few tools for helping people manage chronic diseases at home – and chronic diseases account for a significant portion of the nation's health care costs. Mobile technology has the potential to allow patients to perform remote diagnostics, gather valuable trending data on the progression of a disease, and serve as a medium to receive treatment feedback in near-real-time. Innovation in the Mobile Health space requires advancements in new sensing technology, user interface research, and machine learning and prediction, as well as rethinking the regulation (FDA) of health care technology.

- Scientific Search in the 21st Century
  The number of research papers in science, engineering, and medicine has surpassed 100M and is growing by millions each year. Scientists and doctors can no longer keep up, and need new tools to cope with the deluge of information. The success of "big data" and Natural Language Processing methods offers an opportunity to build a new class of search tools aimed at researchers, but private industry is not motivated to do so. Moreover, the research community's reliance on private tools (e.g., Google Scholar) poses a risk to our research productivity in the event such tools are shut down as they are unprofitable. An increase of efficiency of even 10% would be important. Moreover, giving doctors the latest information about treatments, drugs, side effects would save lives and reduce costs.

- IT progress without silicon technology progress
  Yes, we've heard for a while that Moore's law is ending, but now it is real – we have a handful of atoms of dopant in a transistor and feature sizes are <10nm. So what is next? Analog? Bio-inspired systems? Inexact/approximate computers? This applies to both storage and compute.

- Making hardware design as easy and writing software
  We are already seeing a clear increase in custom hardware design due to limited performance of commodity systems. This will certainly continue to grow and probably accelerate. So how do we make hardware design more accessible? On a related note, we need to be really effective of doing hardware-software co-design.

- Borrowing parts from living systems to build better computers
  DNA is a hugely dense storage molecule for living systems. Can we use it in computers? Neurons have ultra-efficient ion-pumps that act like electrical switches that are many orders of magnitude more efficient than transistors can ever be. Can we use those pumps to build circuits? This is beyond bio-inspired, it is about borrowing actual parts from living systems.

- Ultra-dense storage – to enable storing data that we have to throw away
  Despite all of the "big data" claims, we still throw tons of data away because we can't store it cost-effectively. The live cameras in the U.S. produce ~20PB/day (based on a rough estimate of about 1M cameras), most of which is thrown away. The density of storage devices is not growing fast enough. We need clear step-functions here.

- Synthesis of everything
  Automated synthesis of software is making huge strides. Can we apply it to physical objects (for 3D printing, distributed manufacturing, etc.)?

- Engineering biological machinery with CS principles
  Can we make drug development be more like software development? (A civil engineer would of course ask, "Can we make software development more like bridge design?")

- Large-scale continuous computer vision
  Facebook users alone upload over 300M photos a day, and YouTube users upload over 300 hours of video per minute. How do we do computer vision over that? If we could do effective processing of these visual data, the applications would be amazing: privacy control (I can choose my face to be blurred in all photos), continuous 3D reconstruction of the entire world, content-based image and video search, crime enforcement, etc.

- Keeping systems secure as complexity keeps growing
  Security issues are inherent to the complexity of computer systems. One could argue that it is impossible to make systems secure by construction. Cancer is inherent given the complexity of our bodies. Nature evolved immune systems for the security of its individuals. Can we/should we do the same for computers?

- Scaling infrastructure for "natural user interfaces"
  The computational demand on the back-end of voice-based interaction like Siri and Google voice-based search is tremendous. If everyone started using voice-based interaction tomorrow, systems would crawl. How do we scale that? This is bigger than the "exascale" problem.

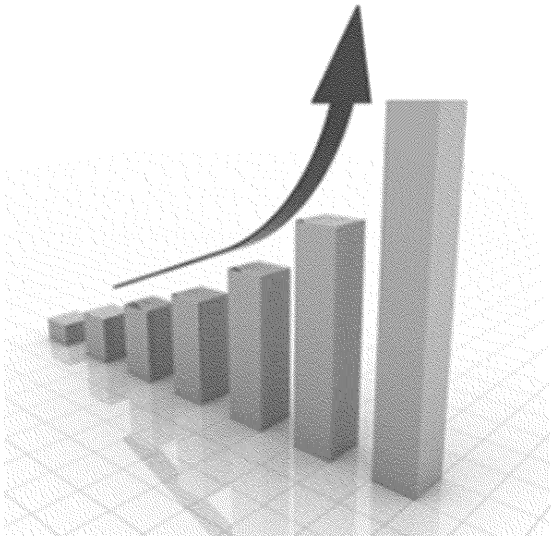
- How can computers help us teach more students more effectively?
  Today's MOOCs are just the tip of the iceberg.

- Can intelligent roads and intelligent cars reduce road accident deaths?
  They certainly can drive a lot better than most of my neighbors.

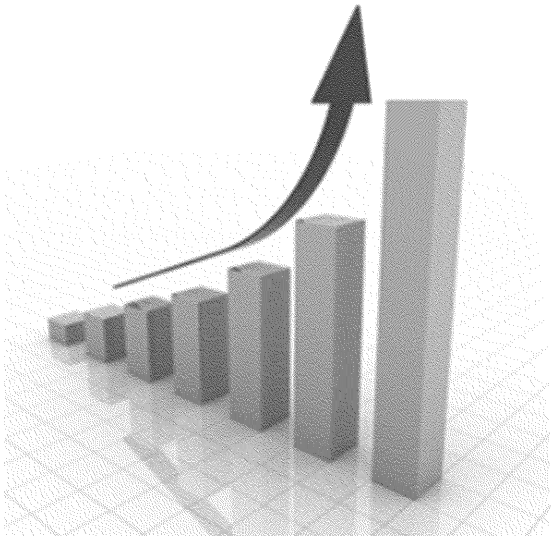
- Can we formally specify (at least part of) the legal code and use computers as judges?

Today, these exponential improvements in technology and algorithms are enabling a "big data" revolution

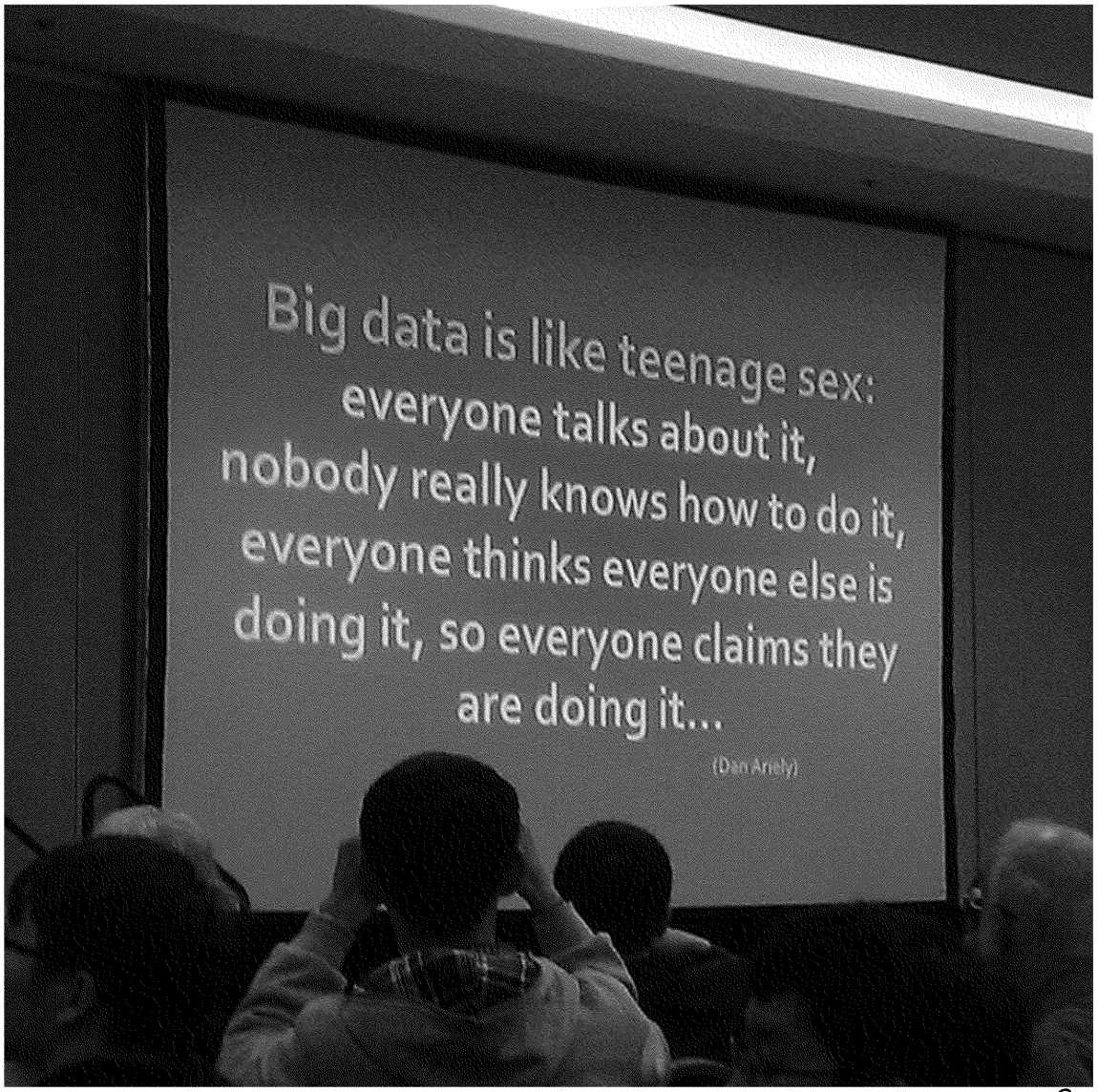
- A proliferation of sensors
  - Think about the sensors on your phone
- More generally, the creation of almost all information in digital form
  - It doesn't need to be transcribed in order to be processed
- Dramatic cost reductions in storage
  - You can afford to keep all the data
- Dramatic increases in network bandwidth
  - You can move the data to where it's needed



- Dramatic cost reductions and scalability improvements in computation
  - With Amazon Web Services, 1000 computers for 1 day costs the same as 1 computer for 1000 days
- Dramatic algorithmic breakthroughs
  - Machine learning, data mining – fundamental advances in computer science and statistics
- Ever more powerful models producing ever-increasing volumes of data that must be analyzed



So, exactly what is meant by “big data”?

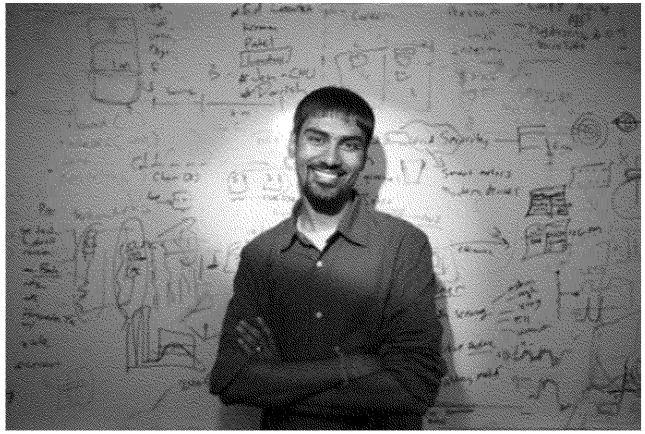


Credit: Dan Ariely, Duke University

Serious answer: "big data" is enabling computer scientists to put the "smarts" into everything

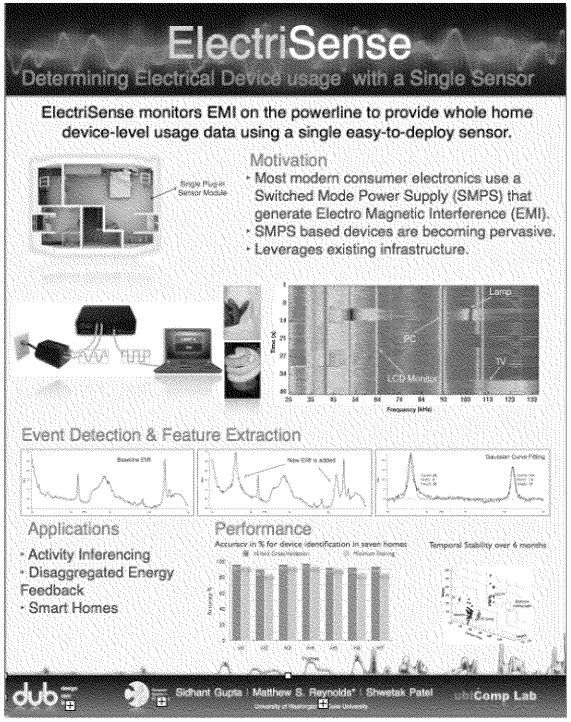
- Smart homes
- Smart cars
- Smart health
- Smart robots
- Smart crowds and human-computer systems
- Smart education
- Smart interaction (virtual and augmented reality)
- Smart cities
- Smart discovery

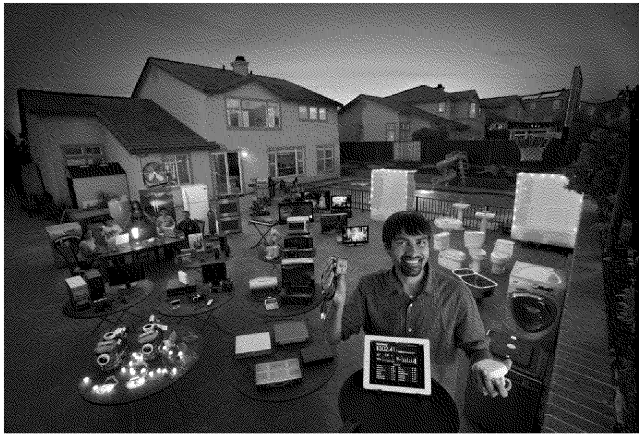
Smart homes (the leaf nodes of the smart grid)



Shwetak Patel,
University of Washington
2011 MacArthur Fellow

MACARTHUR
The John D. and Catherine T. MacArthur Foundation





belkin echo

Smart cars

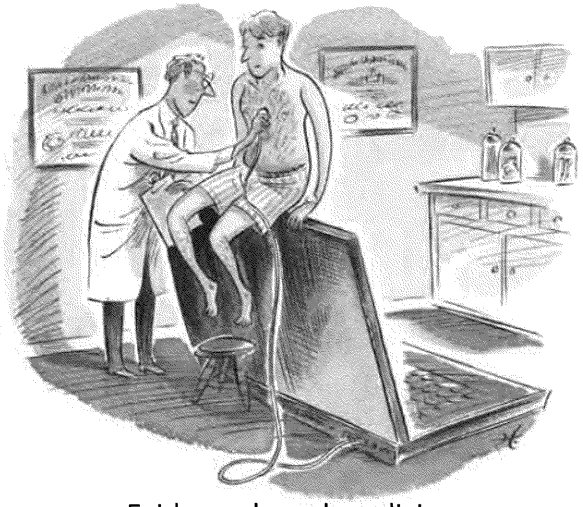
DARPA Grand Challenge

DARPA Urban Challenge

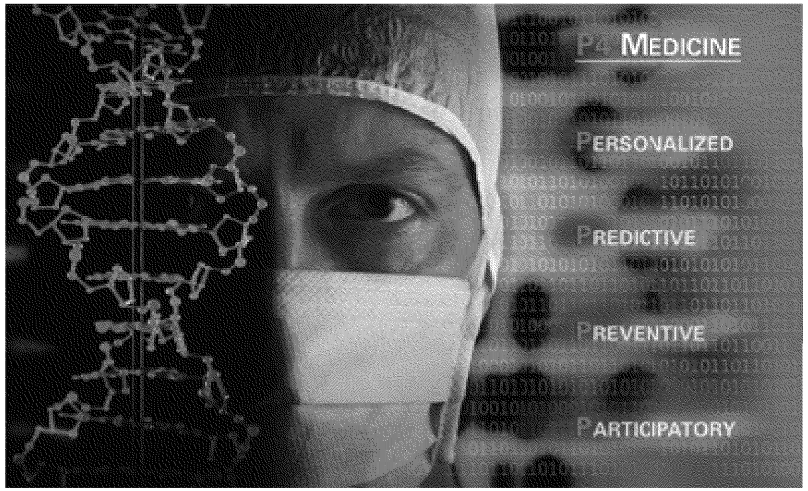
Google Self-Driving Car

Smart health

Larry Smarr – "quantified self"



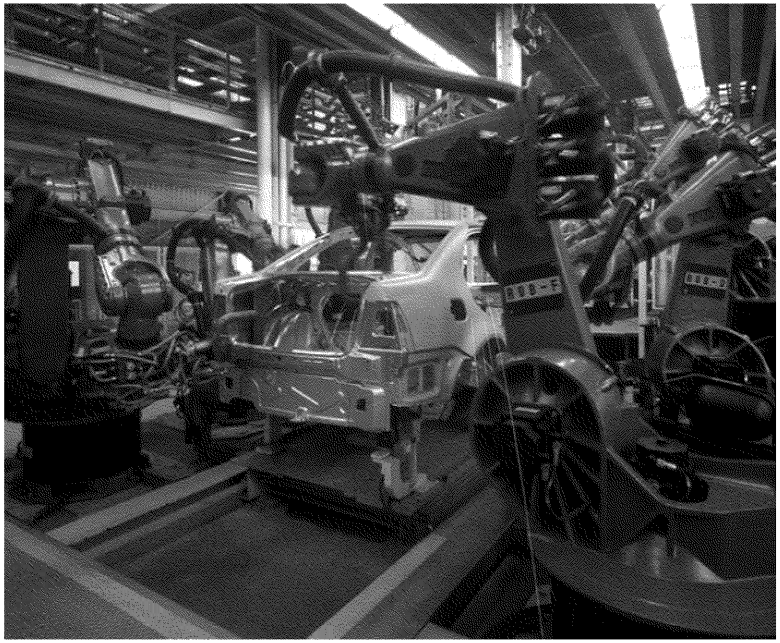
Evidence-based medicine

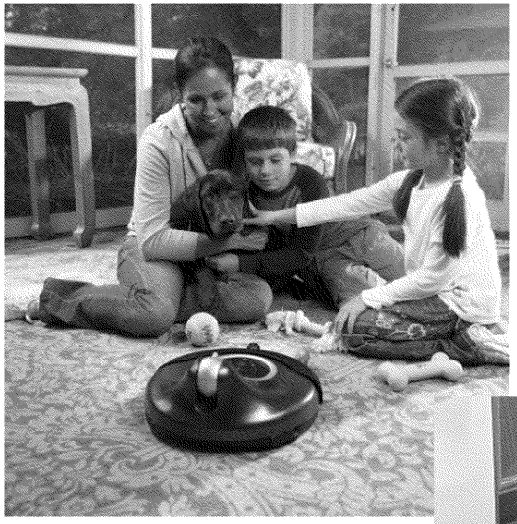


PIONEER 100
HUNDRED PERSON WELLNESS PROJECT
Institute for Systems Biology

P4 medicine

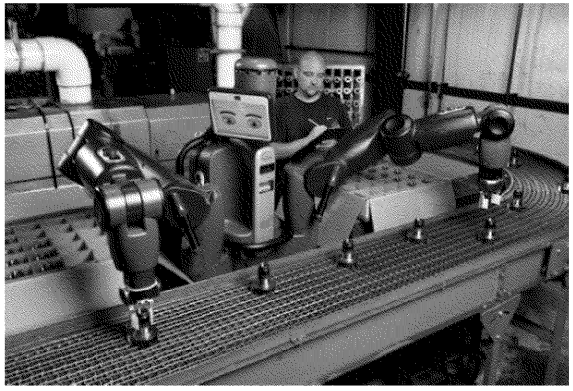
Smart robots





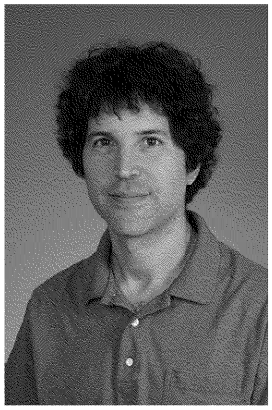
iRobot

rethink robotics

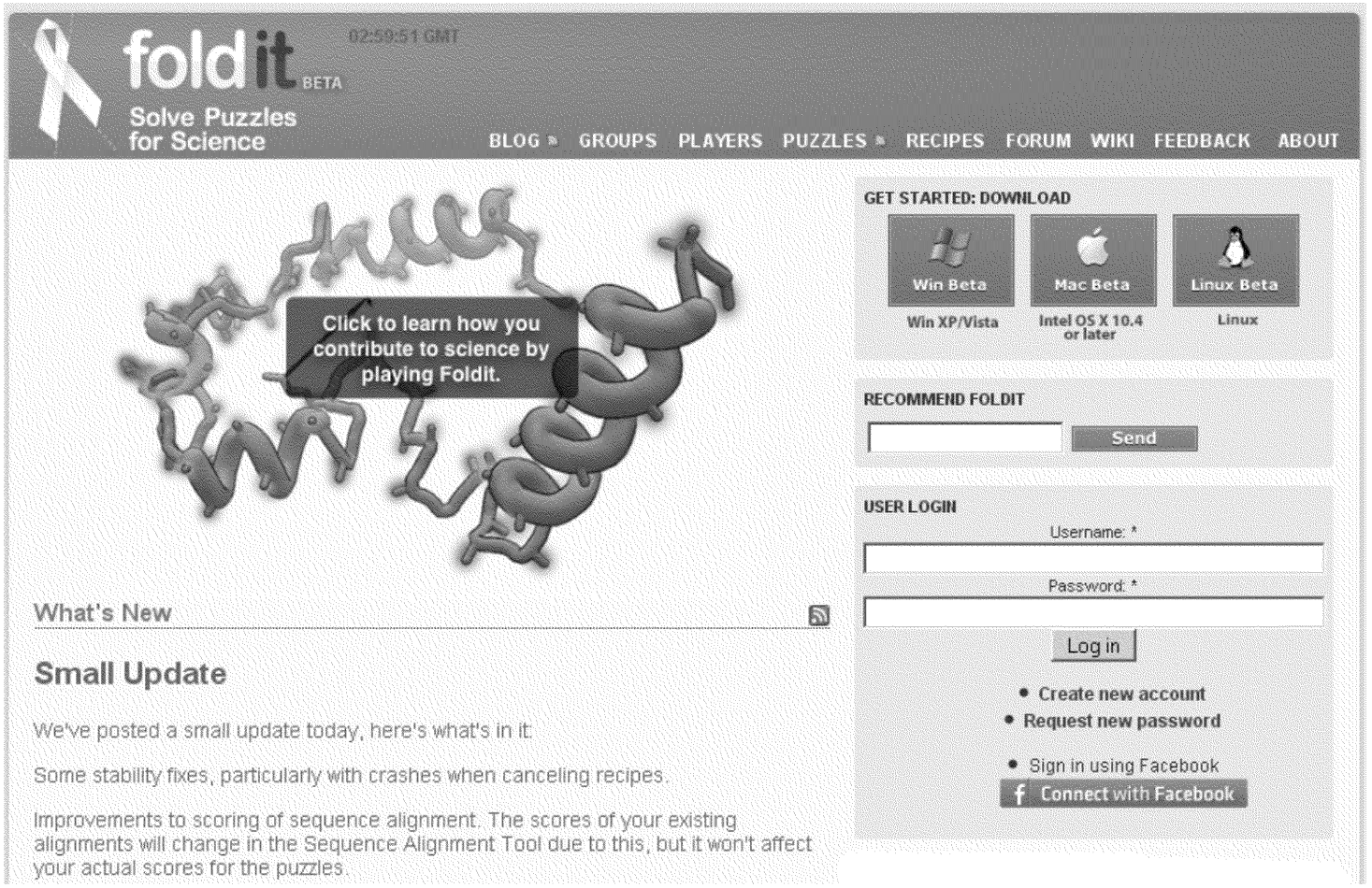


Smart crowds and human-computer systems

Zoran Popovic,
UW Computer Science & Engineering



David Baker,
UW Biochemistry



Smart education

Zoran Popovic,
UW Computer Science & Engineering

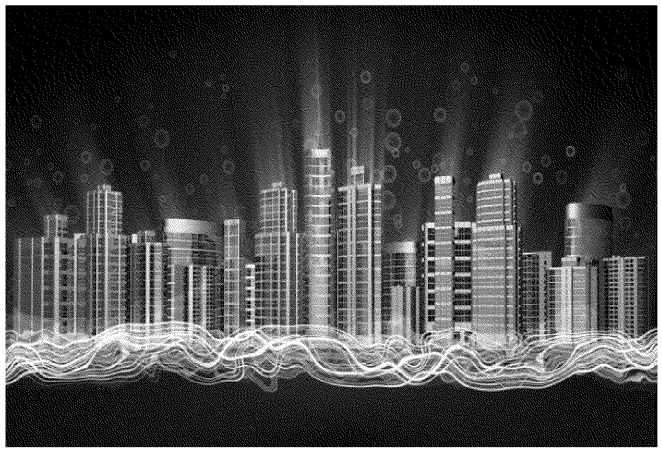
CGS Center for Game Science

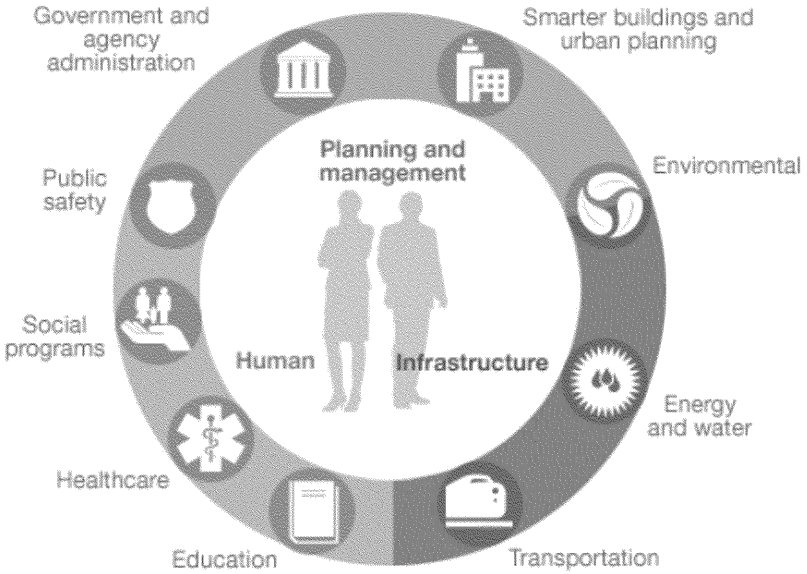
Enlearn

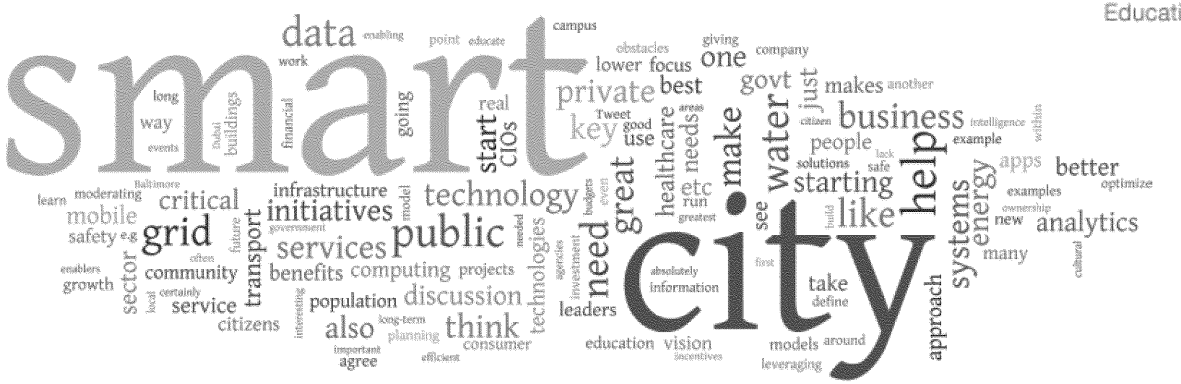
Smart interaction

KINECT™
for XBOX 360

Smart cities

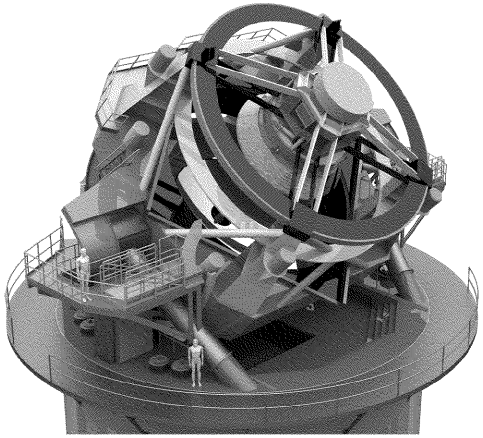




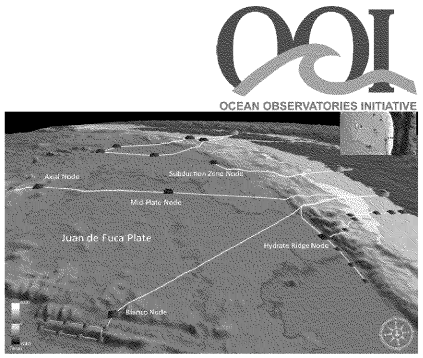


Smart discovery (data-intensive discovery, or eScience)

Nearly every field of discovery is transitioning from "data poor" to "data rich"

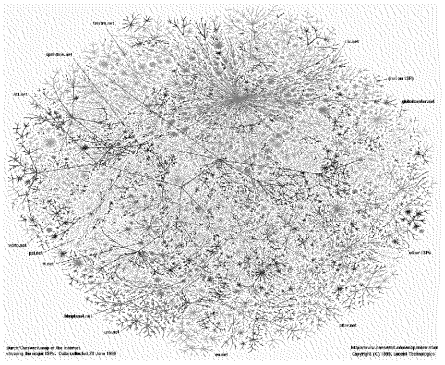


Astronomy: LSST



Oceanography: OOI

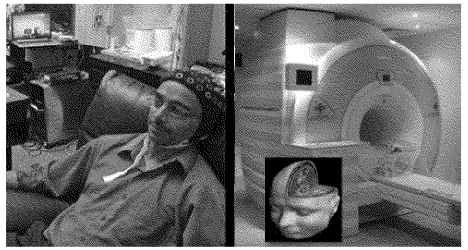
Physics: LHC



Sociology: The Web

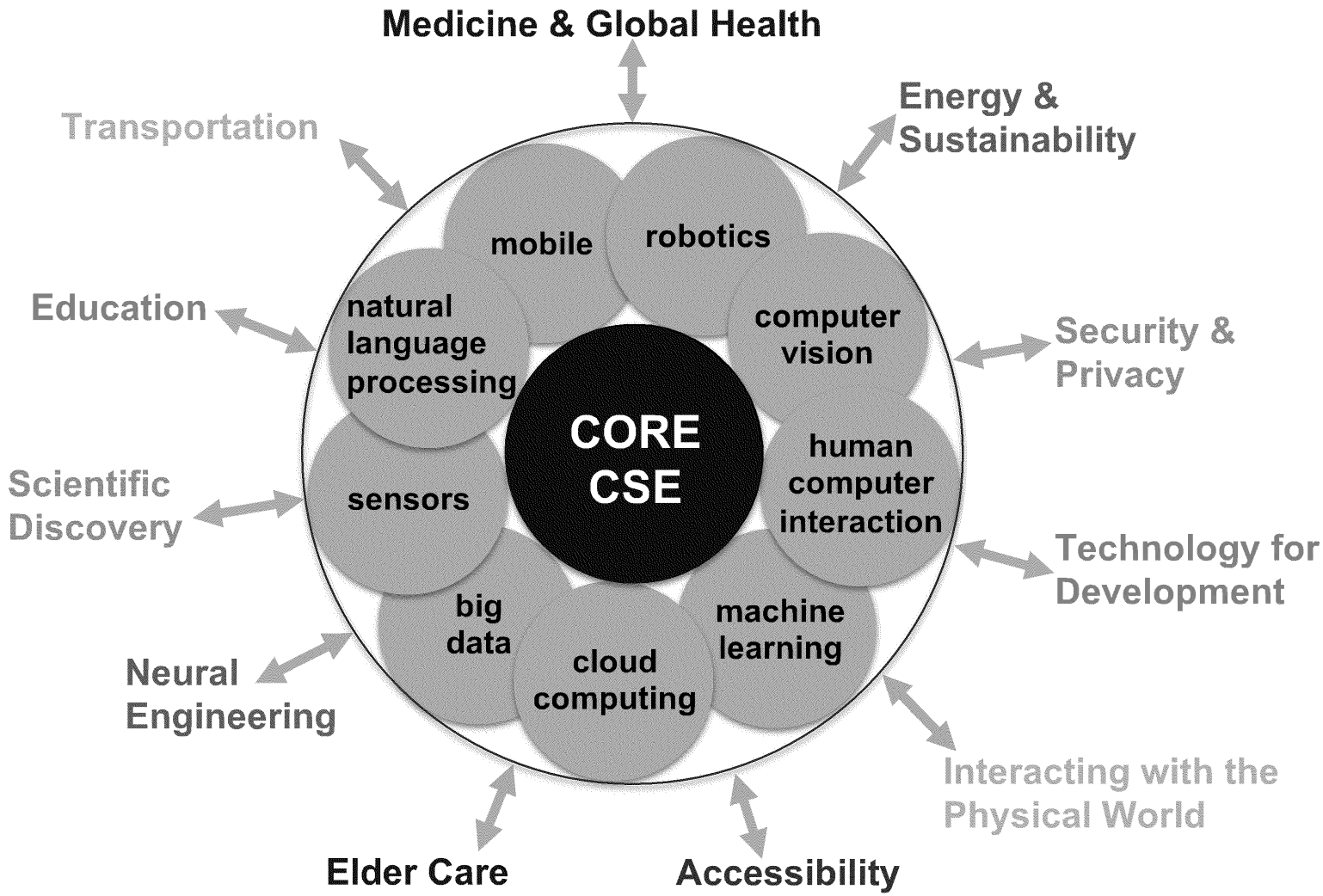
Biology: Sequencing

Economics: POS terminals



Neuroscience: EEG, fMRI

A 21st century view of Computer Science: A field that's unique in its societal impact



From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Saturday, March 7, 2015 9:18 PM

To: Paul Allen

Subject: Progress on CSE2

Attachments: CSE2 Progress.pdf

Paul,

I had figured on seeing you at the AI2 board meeting, and printed a handout regarding progress on the CSE2 building, since you're always kind enough to inquire when we see each other. (We had a really good board meeting - and you made it back in time to sign Marshawn!!!!!) I've attached a pdf of that handout.

The first page is an overall chronology.

The second page is a photograph of the site, taken from a little drone. The shot is from the east, facing west. The Allen Center is at the center. The preferred site is in front - the squat little building is the mothballed reactor building.

The third page is an initial concept from a feasibility study performed by LMM Architects last fall. It shows how CSE2 might fit on that site.

The fourth page is almost not worth including - it's an artist's conception of how the exterior of CSE2 would provide a pathway up the hill from the basketball stadium and the IMA to the Allen Center (which you can see at the head of the stairs). But it's from the feasibility study - we don't have a final design yet. So this is some artist's imagination at work ...

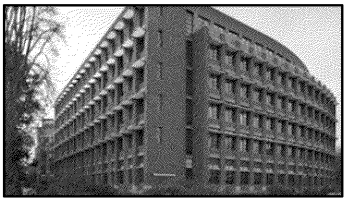
The fifth page is something we review every week. We have weekly meetings of the entire design team, and additional meetings each week of subgroups. Things are going full speed ahead. Separately, UW is working out the issues related to our ability to use the site. UW is 99.9% certain it will all work out, although it's hard to predict the precise twists and turns that things might take. Hank Levy and I had a meeting with everyone involved in this (including the legal team) a couple of weeks ago and we came away very much reassured that they are thoroughly and conscientiously thinking about all the angles and all the measures and counter-measures; I honestly felt really good at the conclusion of this 2-hour session.

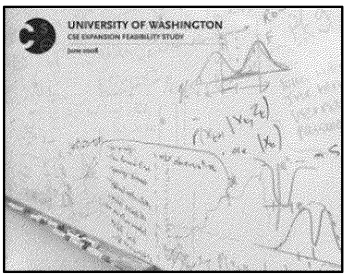
The final few pages are a letter to the Legislature supporting an appropriation for partial funding of the building; Bert was kind enough to sign it, along with 22 others. I am hopeful that computer science, from K-12 through higher ed, will actually get some attention from the Legislature this session, despite the state's financial constraints.

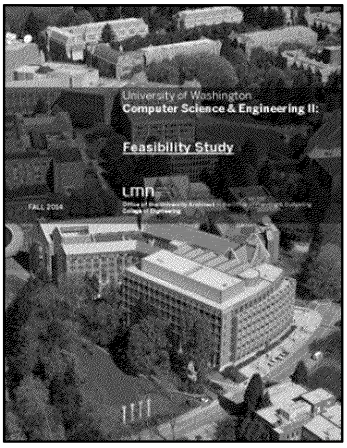
That's the scoop. We're moving ahead full speed.

UW CSE Chronology

- **1967:** Established as an inter-college graduate program, the *Computer Science Group*; housed in the basement of Roberts Hall ("the mining building")
- **1975:** Undergraduate program in Computer Science established; departmental status conferred as the *Department of Computer Science* reporting to both the College of Arts & Sciences and the College of Engineering; moved to Sieg Hall
- **1979:** Reporting relationship changed to the College of Arts & Sciences
- **1989:** Reporting relationship changed from the College of Arts & Sciences to the College of Engineering; undergraduate program in Computer Engineering established; name changed to *Department of Computer Science & Engineering*
- **1996:** Professional Masters Program (part-time, evening/distance, for fully-employed professionals) introduced
- **2003:** Dedication of the Paul G. Allen Center for Computer Science & Engineering (project began in 1999; 2 years of design + 2 years of construction)
- **2008:** Five-year combined Bachelors/Masters program added
- **2008:** Informal *CSE Expansion Feasibility Study* conducted on behalf of CSE by Lee Copeland of Mithun (and, at the time, the UW Campus Architect)
- **2014:** The Office of the University Architect completes a *Computer Science & Engineering II Site Evaluation Report* identifying a preferred site and several alternates
- **2014:** Formal *Computer Science & Engineering II Feasibility Study* conducted on behalf of UW by LMN Architects
- **2014:** $40 million request for partial funding of CSE2 included in Governor Inslee's proposed capital budget
- **2015:** UW Regents select LMN Architects to carry out formal pre-design for CSE2; the process will include an in-depth environmental impact statement for the preferred site
- **2015:** Twenty-three technology leaders write the Legislature supporting the capital budget request



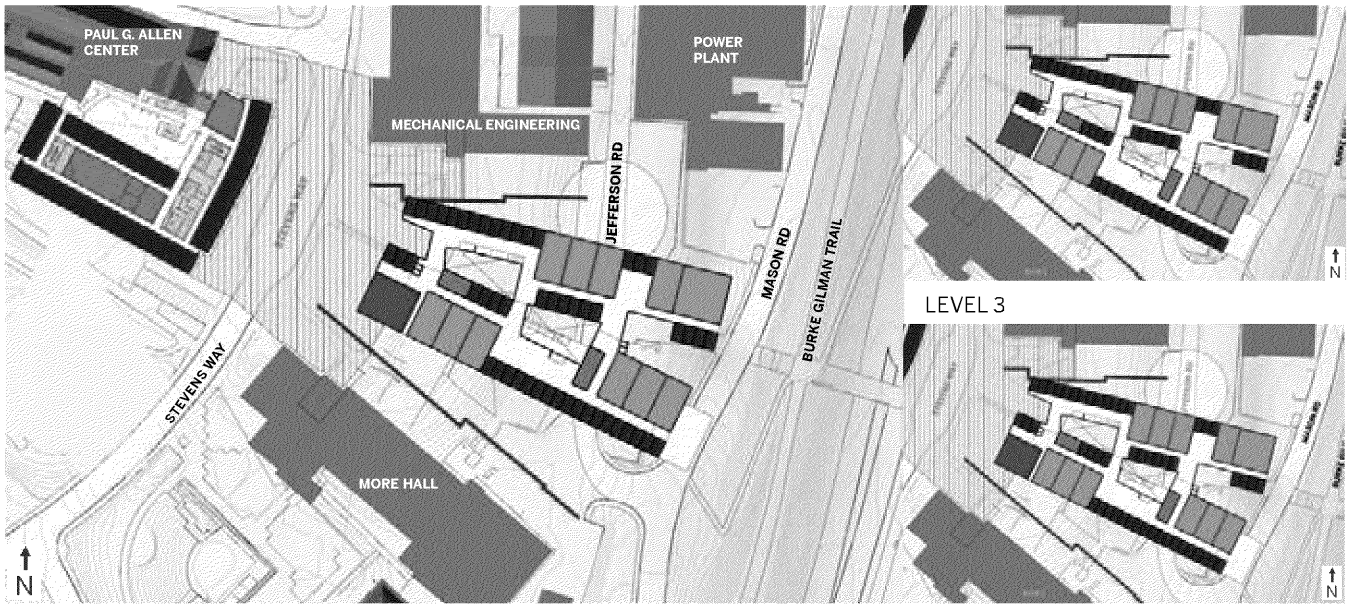




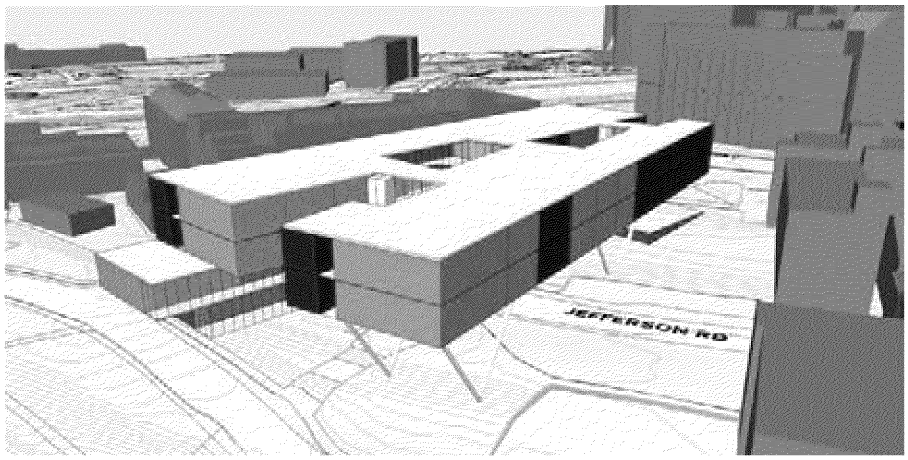
5. Building Concept C

Scheme C

Scheme C opens up further than B to the pedestrian link, spanning over, incorporating and engaging the pedestrian path underneath the building. The south bar of the building is grounded into the hillside and the north bar is expanded across the site to align parallel to a view corridor to Lake Washington. The expanded floor plate allows the program to be accommodated in 4 stories, eliminating the partial 5th floor of A and B. Large light wells and openings through the center of the building allow daylight to reach the ground plane as well as the interior spaces of the building. Lab space and office space is alternated along the edges of the building to create a fully integrated "neighborhood" relationship with opportunities for interaction between faculty of different areas of study and students. Views and access between labs, offices and student study spaces exist throughout the floor,creating a lively and interactive environment.



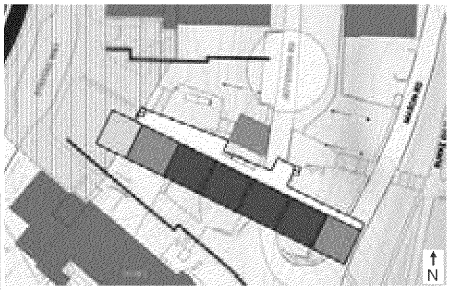
Scheme C Site Plan



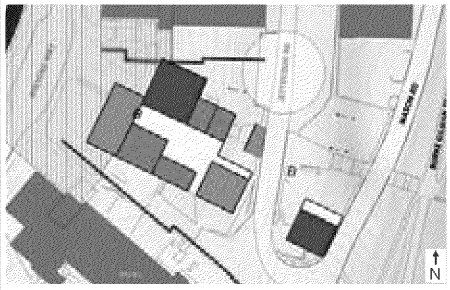
Scheme C Perspective View

LEVEL 3

LEVEL 2



LEVEL 1



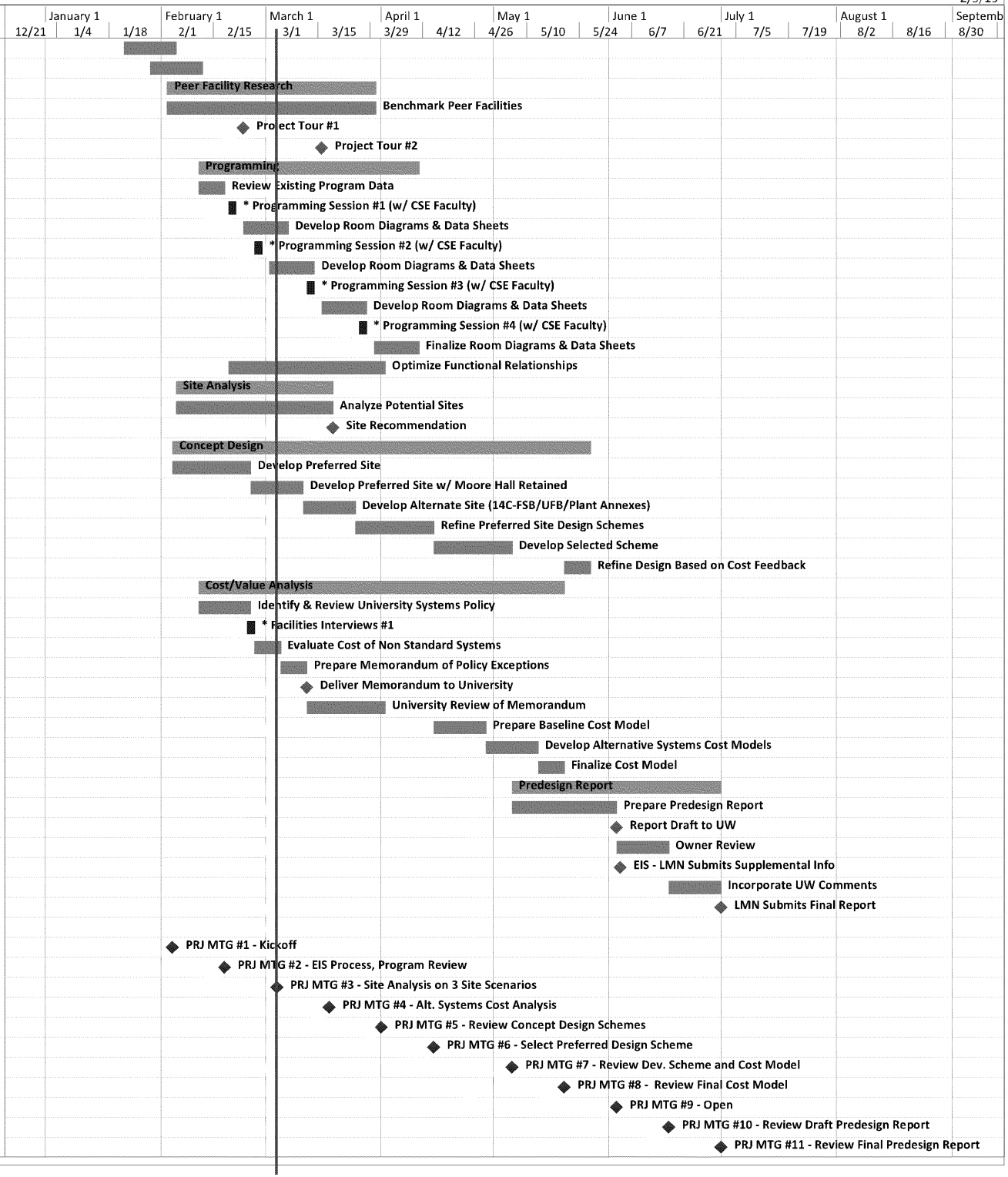
BASEMENT

Scheme C Floor Plans

UW CSE II Predesign Schedule - DRAFT

2/3/15

Task Name	Start	Duration
Sub Consultant Selection	1/22/15	2 wks
Proposal & Contract	1/29/15	2 wks
Peer Facility Research	**2/2/15**	**8 wks**
Benchmark Peer Facilities	2/2/15	8 wks
Project Tour #1	2/23/15	0 wks
Project Tour #2	3/16/15	0 wks
Programming	**2/11/15**	**8.6 wks**
Review Existing Program Data	2/11/15	1 wk
* Programming Session #1 (w/ CSE Faculty)	2/19/15	2 days
Develop Room Diagrams & Data Sheets	2/23/15	2 wks
* Programming Session #2 (w/ CSE Faculty)	2/26/15	2 days
Develop Room Diagrams & Data Sheets	3/2/15	2 wks
* Programming Session #3 (w/ CSE Faculty)	3/12/15	2 days
Develop Room Diagrams & Data Sheets	3/16/15	2 wks
* Programming Session #4 (w/ CSE Faculty)	3/26/15	2 days
Finalize Room Diagrams & Data Sheets	3/30/15	2 wks
Optimize Functional Relationships	2/19/15	6 wks
Site Analysis	**2/5/15**	**6 wks**
Analyze Potential Sites	2/5/15	6 wks
Site Recommendation	3/18/15	0 wks
Concept Design	**2/4/15**	**16 wks**
Develop Preferred Site	2/4/15	3 wks
Develop Preferred Site w/ Moore Hall Retained	2/25/15	2 wks
Develop Alternate Site (14C-FSB/UFB/Plant Annexes)	3/11/15	2 wks
Refine Preferred Site Design Schemes	3/25/15	3 wks
Develop Selected Scheme	4/15/15	3 wks
Refine Design Based on Cost Feedback	5/20/15	1 wk
Cost/Value Analysis	**2/11/15**	**14 wks**
Identify & Review University Systems Policy	2/11/15	2 wks
* Facilities Interviews #1	2/24/15	2 days
Evaluate Cost of Non Standard Systems	2/26/15	1 wk
Prepare Memorandum of Policy Exceptions	3/5/15	1 wk
Deliver Memorandum to University	3/11/15	0 wks
University Review of Memorandum	3/12/15	3 wks
Prepare Baseline Cost Model	4/15/15	2 wks
Develop Alternative Systems Cost Models	4/29/15	2 wks
Finalize Cost Model	5/13/15	1 wk
Predesign Report	**5/6/15**	**8 wks**
Prepare Predesign Report	5/6/15	4 wks
Report Draft to UW	6/3/15	0 wks
Owner Review	6/3/15	2 wks
EIS - LMN Submits Supplemental Info	6/3/15	0 wks
Incorporate UW Comments	6/17/15	2 wks
LMN Submits Final Report	6/30/15	0 wks
Project Meetings (PRJ MTG)		
PRJ MTG #1 - Kickoff	2/4/15	0 wks
PRJ MTG #2 - EIS Process, Program Review	2/18/15	0 wks
PRJ MTG #3 - Site Analysis on 3 Site Scenarios	3/4/15	0 wks
PRJ MTG #4 - Alt. Systems Cost Analysis	3/18/15	0 wks
PRJ MTG #5 - Review Concept Design Schemes	4/1/15	0 wks
PRJ MTG #6 - Select Preferred Design Scheme	4/15/15	0 wks
PRJ MTG #7 - Review Dev. Scheme and Cost Model	5/6/15	0 wks
PRJ MTG #8 - Review Final Cost Model	5/20/15	0 wks
PRJ MTG #9 - Open	6/3/15	0 wks
PRJ MTG #10 - Review Draft Predesign Report	6/17/15	0 wks
PRJ MTG #11 - Review Final Predesign Report	7/1/15	0 wks



Representative Hans Dunshee
Washington State House
PO BOX 40600
Olympia, WA 98504

Dear Representative Dunshee,

We are writing to express our collective support of the University of Washington's request for $40 million in the FY 2015-17 state capital budget for the construction of a 130,000 square-foot Computer Science & Engineering building.

Our region's computer science community has fast become one of the leading areas for growth and innovation in the country. Home to the world's largest software company, online retailer, and online travel company, our stellar pool of talent is charting new territory in mobile technology, enterprise software, cloud computing, interactive media and cyber security. The University of Washington is a huge engine for this industry, home to one of the top ten programs in the nation.

The UW Computer Science & Engineering program (CSE) is among the top national suppliers of students to leading high-tech firms, countless regional tech firms, and startups in our state. In the course of their education, the majority of CSE undergraduates participate in co-ops or internships with these local companies. Because Washington State has such a vibrant computing industry, more than two-thirds of UW CSE graduates remain in state. The UW CSE program is engaged in a broad range of research and interdisciplinary initiatives that produce far-reaching educational and economic benefits to the university and region.

The UW Computer Science & Engineering program (CSE) is at capacity and cannot accommodate current programmatic needs, let alone the growth needed to meet the documented demands for CSE and STEM professionals. The significant rate of growth at every level (undergraduate students, graduate students, faculty, teaching assistants, staff, postdocs, industry partners, etc.) is due to the success of UW CSE's cutting-edge instruction and research initiatives that produce highly skilled and desirable CSE graduates. In the past decade, undergraduate majors in CSE have increased by two-thirds, graduate majors increased 50%, and annual enrollment in CSE's introductory courses has more than doubled. Despite this significant growth in the size of CSE's program, in the last admissions cycle CSE was able to accommodate less than one-third of the undergraduate applicants due to capacity limitations.

CSE is largely housed in the Paul G. Allen Center for Computer Science & Engineering, which opened in 2003 and quickly became a national model for new computer science facilities. The Allen Center and its state-of-the-art laboratory space revolutionized the nature of CSE research and education; it had a dramatic impact on UW CSE's competitiveness, supporting UW CSE to become a national leader. The space in the Allen Center is full with the current activities. Growth, especially for undergraduate studies and degrees, is not possible with the current constraints on space. In June 2014, UW Seattle CSE program granted 315 degrees —the largest graduating class ever.

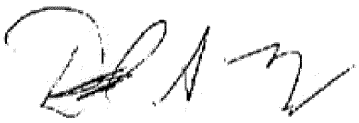
This LEED-silver project will deliver a 130,000 square foot building, creating new instructional spaces, undergraduate student spaces, research and educational labs, shops, offices and event spaces for UW CSE. The project will enable further expansion not only of CSE's educational programs, but also of CSE's interdisciplinary collaboration in data-driven discovery, K-12 education technologies, and activities aimed at applying computing to global challenges, such as energy, health, security and privacy, and education.

As representatives of companies and businesses that rely on a ready supply of high quality computer science graduates, we believe it is critical for the State to invest in this sector in a way that ensures its vibrancy and growth. Our vision is for Washington to continue to lead the way in technology and computer science, but we must keep pace with the vast demand. This investment from the State is an ideal way to showcase our exceptional local resources and work force as we compete globally in this market. With the state's investment, we understand the UW would generate more than the remaining half of the total project cost through other local sources and public-private partnerships.

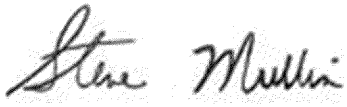
Please help us make sure Washington state continues to maintain its place at the forefront of the computer science industry and sets a strong base for future growth by ensuring UW can continue to produce the graduates we need by including $40M in the University of Washington's state capital budget toward the construction of a new Computer Science & Engineering building.

Sincerely,

Brad Smith
Microsoft Corporation

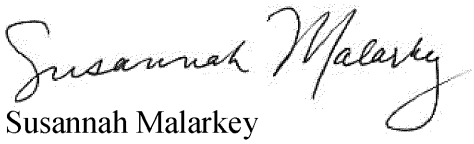


David A. Zapolsky
Amazon

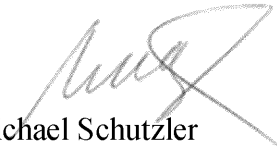


Steve Mullin
Washington Roundtable

Maud Daudon
Seattle Metropolitan Chamber of Commerce

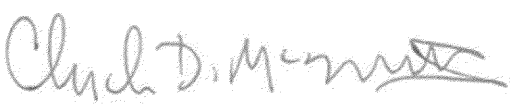


Susannah Malarkey
Technology Alliance



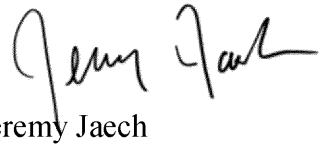
Michael Schutzler
Washington Technology Industry Association

Paul Carduner
Facebook Seattle



Clyde D. McQueen III
Google Seattle

Bert Kolde
Vulcan, Inc

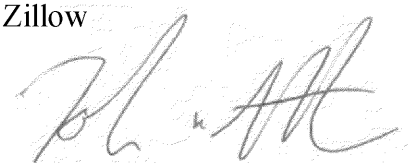


Jeremy Jaech
SNUPI Technologies

Patrick Jenny
F5 Networks

Rich Barton
Zillow

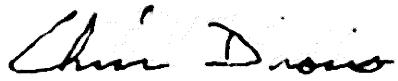
Tom Alberg
Madrona Venture Group



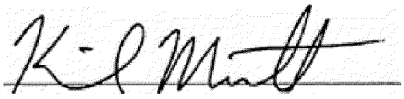
John Stanton
Trilogy Partnership

Chris Stolte
Tableau Software

Sarah Bird
Moz



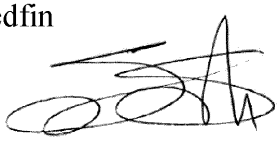
Chris Diorio
Impinj



Kevin Merritt
Socrata

Glenn Kelman
Redfin

Sunny Gupta
Apptio



Steve Singh
Concur

Hadi Partovi
Code.org

Brad Silverberg
Ignition Partners

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Monday, March 13, 2017 10:18 AM
To: Ana M. CAUCE;Pat Shanahan;Paul Allen;Brad Smith;Kristin Osborne;Steve Lombardi
Subject: Photos from GeekWire
Attachments: 20170309_Paul_Allen_UW_CSE_179.jpg

20170309_Paul_Allen_UW_CSE_185.jpg

Todd Bishop sent me two nice "toasting" photos. Attached. (One as an attachment, one as a Google Drive link.)


UNIVERSITY of WASHINGTON
COMPUTER SCIENCE & EN
50
ANNIVER
EBRA

From: Ed Lazowska <lazowska@cs.washington.edu>

Sent: Sunday, November 15, 2015 10:18 PM

To: Paul Allen

Subject: Thanks, and a status report

Attachments: UW CSE2 status for Paul.pdf

Paul,

Thanks for the game. Unfortunate outcome, but always a wonderful experience to be there. Lyndsay and I appreciate the opportunity hugely.

I've attached a pdf with a status report on the CSE2 building project. (The first 2.5 pages are the status report; there are some attachments.) Getting the building going has had to take priority over all else, because we simply must accommodate growth - we're out of space in the Allen Center to the extent that we've re-occupied one floor of Sieg Hall, which we hoped never to see again when we moved out in 2003!

Thanks again! And also, thanks for the invitation to the South East Asia trip - a once-in-a-lifetime opportunity for us!!

UW Computer Science & Engineering CSE2 Project Information

Ed Lazowska, 11/15/2015

UW CSE overview

You know my personal goal, and you know that I'm obsessed with it

- To create, at UW, a computer science program that's truly in the first rank
- To do this in the context of a public university
  - Educating Washington students
  - Sending them to Washington jobs
    - Amazon has been the largest employer of our students in recent years
  - Engaging in innovation, entrepreneurship, collaboration, and outreach that differentially benefit Washington companies and Washington's economy

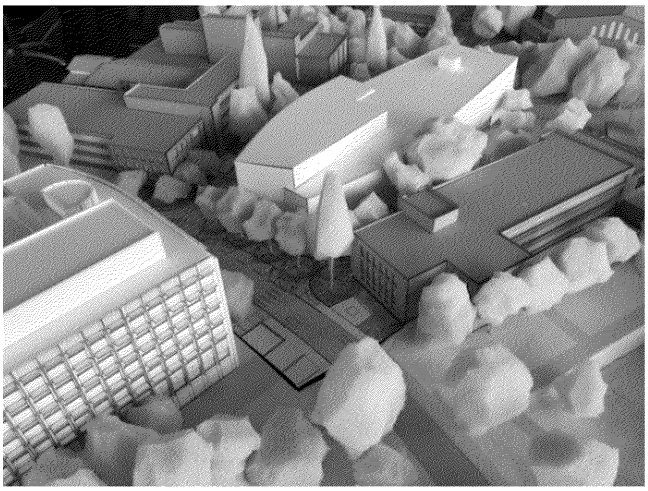
We are on the verge of pulling this off

- We are close to being truly a #1 program
  - We only compete for faculty and graduate students with Berkeley, MIT, Stanford, and Carnegie Mellon – and we are breaking even with Carnegie Mellon
    - See the attached write-up "UW Computer Science & Engineering's National Standing"
- Our track record of regional engagement and impact is excellent
  - More than 3/4^{ths} of our students are WA residents; more than 3/4^{ths} remain in WA after graduation
  - We have a strong record of innovation, entrepreneurship, collaboration, and outreach
- We are a national leader in increasing the participation of women in the field (although we would be the first to admit that we have a long way yet to go)
  - Last spring we received the first-ever annual national award from the National Center for Women & Information Technology for success in encouraging women to pursue computer science
  - At UW, women receive twice the percentage of computer science bachelors degrees as the average for bachelors programs at research-intensive universities
    - See the attached write-up "UW Computer Science & Engineering: A leader in promoting gender diversity in computing"
- We have the opportunity to grow significantly, increasing our impact
  - Student demand – at UW and elsewhere – is breaking all records at all educational levels
    - For example, in the past year we enrolled more than 3,000 students in our "CS1" course
  - The Legislature is on track to double our majors enrollment at all degree levels from what it was just two years ago

The CSE2 building project

The immediate task ahead of us is to raise the funds for a new building to accommodate this growth

- It's in design now – we're halfway through the process
    - LMN (specifically Mark Reddington) is the architect – they/he designed the Paul G. Allen Center
        - Mortenson is the general contractor – again, just as for the Allen Center
        - Hank Levy is once again serving as our liaison with the architect and the general contractor
        - This team brought the Allen Center in on-time and several million dollars under-budget (although 2001-03, in contrast to now, was a particularly favorable construction environment)
    - The "preferred site" is across the street from our current building, creating an integrated two-building complex
    - Right now we have a cardboard realization of the design (see photo)
- We hope to break ground a year from now, and to occupy two years after that – autumn 2018
- Projected total cost (design, construction, furnishing, sales tax, … everything) is $105M-$110M
    - UW committed $5M to get the design work started
    - We received $32.5M from the Legislature
    - Microsoft committed $10M



Cardboard realization of current design on preferred site

The *Campaign for CSE*

Between 2000 and 2005, we raised $42M in private funding for our current building

- 10 donors at $1M or greater
- An additional 25 at $100K or greater
- An additional 55 at $25K or greater
- >200 in all

We raised an equivalent amount in endowments for scholarships, fellowships, and professorship, and new initiatives

The building took priority – it was Job One

- Endowments followed (in many cases from people who got to know us through supporting the building project)

Same story this time

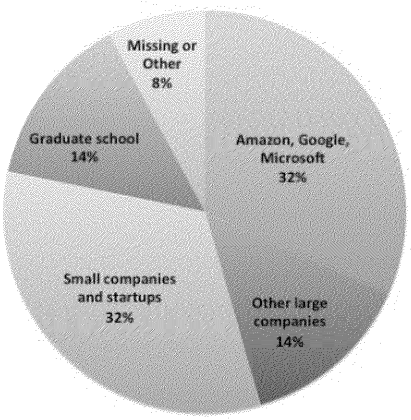
- As part of UW's next campaign – which is in its quiet phase now and will go public in fall 2016 – our goals must be roughly double those amounts
- The CSE2 building is Job One
- For the overall *Campaign for CSE*, we have an exemplary Advancement Committee (to which we plan to add a few more members) that will help us get the job done
    - Chair: Brad Smith (Microsoft President)
    - Co-Chairs:
        - Jeff Dean (Ph.D. alum; Google Senior Fellow)
        - Anne Dinning (Bachelors alum; head of 4-person Executive Committee at D. E. Shaw) and Michael Wolf
        - Sujal Patel (ex-Isilon) and Meera Patel
        - Rob Short (Masters alum; ex-Microsoft Corporate Vice President for Windows Core Technology) and Emer Dooley (Lawrence P. Hughes Faculty Fellow in Innovation and Entrepreneurship, UW)
        - Charles Simonyi (Intentional Software, ex-Microsoft) and Lisa Simonyi
        - Steve Singh (CEO of Concur)

A "UW CSE Fact Sheet" is attached that paints the picture in broad strokes

UW Computer Science & Engineering's National Standing

The most important role that UW CSE plays – the most important role that any top university plays – is to send superbly prepared students to our region's top technology companies. UW CSE is one of the nation's leading suppliers of new graduates at all degree levels to companies such as Microsoft, Amazon, and Google – roughly 1/3 of our graduates go to these three companies. And we are the predominant supplier to the region's startups and smaller companies, and to the more than 50 Seattle engineering offices of companies headquartered elsewhere.

2011-14 UW CSE Student Destinations



It is important to recognize, though, that in addition to its unique role in our region, UW CSE is one of the nation's preeminent computer science programs. For more than 30 years, UW CSE has been ranked among the top 10 computer science programs in the nation, of more than 200 Ph.D.-granting programs. Rankings are not important in and of themselves, but UW CSE's excellence pays off in the quality of our graduates, in the talent that we attract to the region, in the impact of our research, in the quality of our interactions with leading companies, and in the entrepreneurship and innovation of our faculty, students, and alumni.

Traditionally the computer science programs at MIT, Stanford, Carnegie Mellon, and Berkeley have been in a class by themselves – there was a significant gap between these four programs and the programs at UW, Cornell, Princeton, Illinois, Georgia Tech, the University of Texas, and the other strong-but-not-elite programs. In recent years, though, UW has closed the gap with the "top four," and widened the gap with the "strong-but-not-elites." Today UW CSE only competes with MIT, Stanford, Carnegie Mellon, and Berkeley.

The *Campaign for CSE* will cement UW CSE's position as one of the truly elite programs in the nation and the world – as a #1. Here are some indications of the progress we have made:

- A tally by Prof. Jeff Huang of Brown University of "Best Paper Awards" at major computer science technical conferences since 1996 finds essentially a tie among 4 universities, including UW. (Microsoft Research exceeds these universities, but MSR has nearly 1,000 Ph.D. researchers, 10-20 times as many as any university.)

- National Science Foundation Graduate Research Fellowships are the most competitive awards for early-career graduate students in science and

Institutions with Best Papers	
Microsoft Research	41.0
Stanford University	29.2
Carnegie Mellon University	28.4
Massachusetts Institute of Technology	27.9
University of Washington	26.7
University of California Berkeley	19.5
University of Toronto	13.4
Cornell University	12.9
IBM Research	12.2
University of Illinois at Urbana-Champaign	11.9
University of Texas at Austin	10.4
University of British Columbia	10.4
University of California Irvine	7.7
University of Massachusetts Amherst	7.2
Google	7.2
University of Michigan	7.2
École Polytechnique Fédérale de Lausanne	7.1

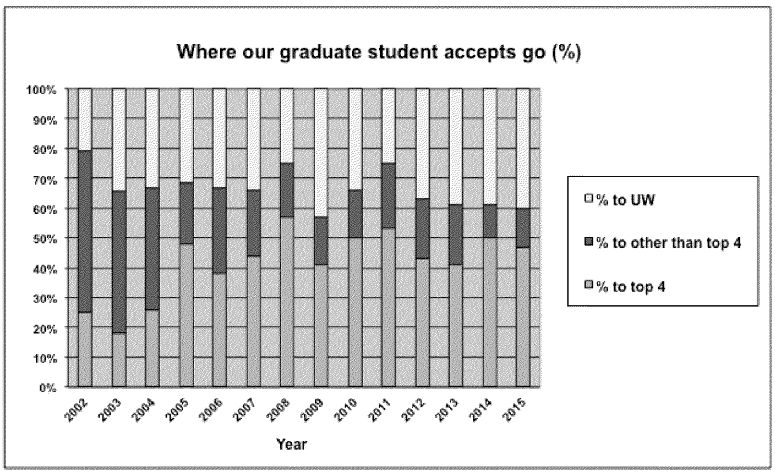
engineering. In 2015, UW and UC Berkeley led the nation in students receiving these fellowships.

2015 National Science Foundation Graduate Research Fellowship Recipients

UC Berkeley	11
University of Washington	10
MIT	7
Stanford	5
Princeton	3
Illinois	3
Cornell	1
Carnegie Mellon	1

- MIT, Berkeley, Carnegie Mellon, Stanford, and UW are in a class by themselves in the placement of Ph.D. alums into faculty positions at top-20 programs – each with double-digit numbers of Ph.D. alums among Assistant Professors in these programs. UW CSE has nearly twice as many Ph.D. alums in Assistant Professor positions at top-20 programs as Princeton, the University of Texas, or Cornell, the programs that immediately trail UW CSE in this tally – a significant gap.

- Our competitiveness for attracting the highest caliber graduate students has steadily increased to the point that each year we lose only an insignificant number (1, or at most 2) to any program outside of the top 4. Against our top 4 peers, we break even against Carnegie Mellon, and we have a number of key wins each year against MIT, Stanford and Berkeley.



- While we are particularly proud of our record of identifying and recruiting to our faculty the very highest potential new Ph.D.s, in recent years we have also recruited a number of mid-career stars away from other top programs, including:
  - Ras Bodik from UC Berkeley
  - Tom Anderson from UC Berkeley
  - Noah Smith from Carnegie Mellon University
  - Carlos Guestrin from Carnegie Mellon University
  - Steve Seitz from Carnegie Mellon University
  - Mike Ernst from MIT
  - Jeff Heer from Stanford University
  - Sham Kakade from Microsoft Research New England
  - Ben Taskar from the University of Pennsylvania
  - Katharina Reinecke from the University of Michigan
  - Matt Reynolds from Duke University

UW CSE has made extraordinary progress towards joining MIT, Stanford, Carnegie Mellon, and Berkeley as a #1 computer science program. Building upon this momentum, the *Campaign for CSE* will make it a reality.

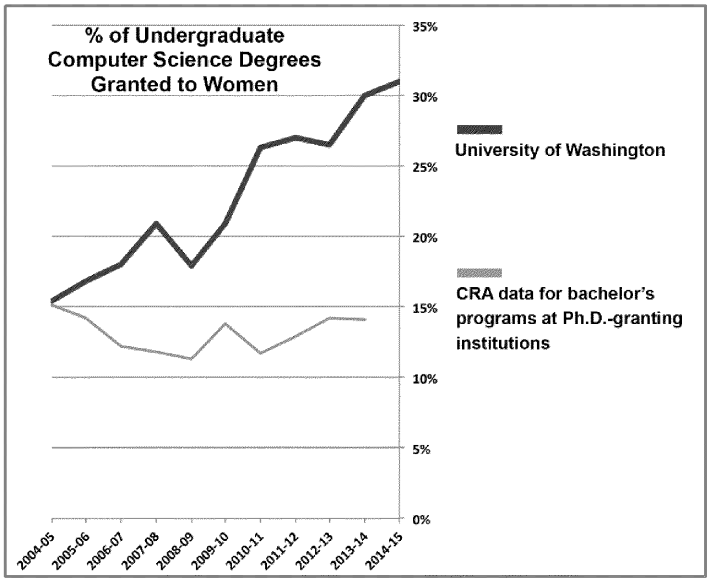
University of Washington Computer Science & Engineering: A leader in promoting gender diversity in computing

University of Washington Computer Science & Engineering (UW CSE) is recognized as a leader in promoting gender diversity in the field of computing. We consistently outpace our peers in the recruitment and retention of women in our undergraduate computer science program, and we are committed to sustaining this momentum and leading the way when it comes to expanding opportunities in computer science education.

Setting the pace

UW CSE joined the National Center for Women & Information Technology's Pacesetters program in 2009, setting a goal to increase the proportion of students in our undergraduate computer science program who are women from 24% to 30%. Over the ensuing five years, we exceeded that goal.

More impressively, in absolute terms we nearly doubled the number of women pursuing computer science at the UW: our undergraduate student body grew from 88 women in 2009 to 162 in 2014, spurred on by a combination of targeted outreach and a growth in overall capacity.



Our efforts are reflected in our graduation rate, illustrating our ability to not only recruit but support and retain women in the major. At our June 2015 graduation celebration, we awarded 31% of our bachelor's degrees in computer science to women – more than twice the national average for bachelor's programs at research-intensive universities.

Focusing on the pipeline

In 2012, UW CSE consolidated our various K-12 outreach activities into a new, expanded outreach program called DawgBytes (slogan: "A taste of CSE"). We also embarked upon a new strategy to engage more young women in computing with the introduction of our summer day camps. More than 60 middle and high school girls participated that first year, and we subsequently expanded our offerings to include both girls-only and co-ed sessions. In 2014, we began focusing even earlier in the pipeline, introducing camps for students in grades 3 through 5.

Since the program's inception, more than 300 students have taken part in our 15 girls-only camps, (and our co-ed sessions have enabled us to reach even more). All told, we have held a total of 31 camps that engaged 615 students from across the state, with scholarships covering the bulk of the costs for students of limited means to mitigate any financial barrier to their participation.

At the university level, we redesigned our suite of introductory courses 10 years ago to focus on three factors that have been crucial in leading more women at the UW to computer science: instilling confidence, cultivating a sense of community, and communicating the potential for impact[1]. Combined enrollment in both introductory courses has skyrocketed to around 5,000 students per calendar year. On average, 36% of students taking our entry-level course are women, and women make up nearly half of the team of undergraduate teaching assistants who lead the course seminars.

Building on our momentum

Based on our continuing commitment and our achievement of tangible results, UW CSE was recognized with NCWIT's inaugural NEXT Award Grand Prize for Excellence in Promoting Women in Undergraduate Computing in May 2015. In its commendation accompanying UW CSE's award, NCWIT observed:

> *The University of Washington has grown an inclusive, welcoming community that spans beyond the walls of the university and has demonstrably advanced women's meaningful participation in computing.*

The award prompted *The New York Times* to publish an article, "Making Computer Science More Inviting: A Look at What Works," that highlighted UW CSE's success in taking steps that address the gender imbalance in this exciting and rapidly expanding field[2].

UW CSE is committed to building on this achievement and working toward even greater diversity: women made up 33% of our 2014 freshman cohort, and we have set a new, more ambitious goal of reaching 40% women in our computer science program. We won't be truly satisfied until we achieve even more.

As eminent computer scientist Bill Wulf, then-president of the National Academy of Engineering, noted more than 15 years ago:

> *Sans diversity, we limit the set of life experiences that are applied, and as a result, we pay an opportunity cost – a cost in products not built, in designs not considered, in constraints not understood, in processes not invented….*
>
> *Every time we approach an engineering problem with a pale, male design team, we may not find the best solution. We may not understand the design options or know how to evaluate the constraints. We may not even understand the full dimension of the problem.*

UW CSE is leading the way in engaging more women in computer science education – which will help shape computing into an even more creative and transformational field that truly benefits *all* of society.

---

[1] View our video about our introductory courses and their role in recruiting women to computer science here.

[2] See our 2013 article, Broadening Participation: The Why and the How, for more details on our efforts to increasing gender diversity in computer science at the University of Washington.

Computer science and computer engineering are changing the world.

UW CSE is driving this revolution.

University of Washington Computer Science & Engineering is revolutionizing the field of computing, driven by a powerful vision of its expanding role in the modern university and in the modern world. We are one of a small number of preeminent programs in the nation, recognized globally for the quality of our teaching and research.

OUR IMPACT

UW Computer Science & Engineering is dramatically expanding our impact on Washington's students, innovative employers and economy — and developing solutions to some of society's greatest challenges.

EDUCATING THE NEXT GENERATION OF INNOVATORS

UW CSE prepares Washington's students for Washington's leading-edge jobs. We are *by far* the top supplier in the state of computer science graduates to innovative companies of all sizes. We empower our students to think globally and to apply computer science and computer engineering to improving quality of life for people around the world.

BREAKING DOWN BARRIERS TO BROADEN PARTICIPATION

UW CSE is committed to broadening participation in computing among under-represented groups and to mentorship, collaboration and service. We demonstrate this commitment every day through robust outreach programs and partnerships that enable students to participate in groundbreaking research, expand opportunities for K-12 students and teachers, and promote entrepreneurial success.

UW CSE AT A GLANCE

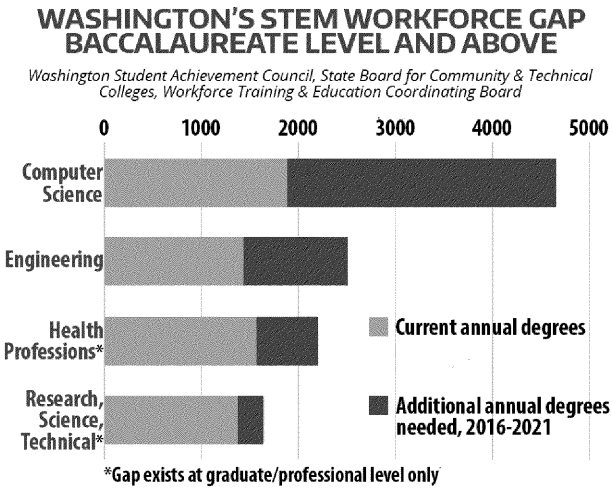
First established in 1967 as the Computer Science Group, Computer Science & Engineering has evolved into one of the University of Washington's most outstanding units, with more than 50 faculty and 75 staff.

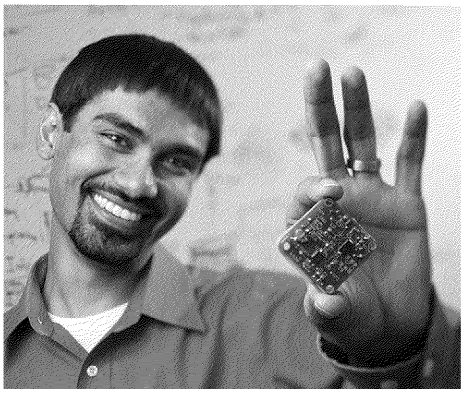
Consistently ranked among the top 10 programs in the nation, UW CSE produces highly effective graduates, conducts high-impact research, engages broadly in interdisciplinary initiatives and in the community, and is active in technology transfer, company creation and entrepreneurship. We compete with only a handful of other top programs to attract the very finest faculty, students and postdoctoral researchers while remaining true to our mission as a unit of Washington's flagship public university.

EDUCATING WASHINGTON'S STUDENTS FOR WASHINGTON'S LEADING-EDGE JOBS

UW CSE is *by far* the top supplier in the state of computer science graduates to innovative companies of all sizes. More than 3/4ths of our students are Washington residents, and the vast majority of our graduates remain here after obtaining their degrees. The opportunity for our citizens is great: Washington's projected workforce gap in computer science exceeds the next three high-demand fields, combined. Nationally, 71 percent of all new STEM jobs in this decade are projected to be in computing.

While we have expanded in response to growing demand, granting 364 degrees in 2014–15, we are able to accommodate only 1/3rd of qualified UW students who apply to the major. We also face growing demand across the campus: we enrolled nearly 5,000 students in our introductory courses during the past year, and the demand for upper-division courses from students in other fields is also rapidly increasing.





Above:

Professor Shwetak Patel displays an ultra-low-power sensor developed in the Ubiquitous Computing Lab. UW CSE faculty and students are using these novel sensors to develop new solutions for mobile health care, sustainability, home networking and many other applications that are enabling the Internet of Things.

Front cover:

Ph.D. student and Ubiquitous Computing researcher Lilian de Greef works on BiliCam, a smartphone-based system for monitoring jaundice in newborns.

PUSHING BOUNDARIES, CHANGING THE WORLD

UW CSE faculty and students are not just pushing the boundaries of the field: they are producing innovations that have the potential to change the world. We are at the forefront of data science, machine learning, natural language processing, computer vision, human-computer interaction, programming languages and software engineering, privacy and security, and wireless and sensor systems — and we are applying this expertise to some of humanity's greatest challenges.

TECHNOLOGY FOR GLOBAL DEVELOPMENT

UW CSE researchers developed a set of open-source, mobile data collection tools, the Open Data Kit, for use in low-resource settings. ODK is currently being used to advance public health, environmental stewardship and humanitarian causes in countries around the globe.

ODK
OPEN DATA KIT

CROWDSOURCING SCIENTIFIC DISCOVERY

UW CSE's Center for Game Science pioneered citizen science through gaming, with remarkable results. Players of our protein folding game, FoldIt, helped solve a scientific mystery by successfully modeling the structure of an enzyme that could lead to novel treatments for AIDS — and they did it in just three weeks.

Center for Game Science

A RECOGNIZED LEADER IN BROADENING PARTICIPATION IN COMPUTING

UW CSE is leading the way in promoting diversity in our field by reaching out to women, people of color and people with disabilities.

INCREASING GENDER DIVERSITY

We set out to address the gender disparity in computer science education by building a welcoming and supportive community and by making a concerted effort to recruit talented women as students and faculty. Designated a Pacesetter School by the National Center for Women & Information Technology, UW CSE was recognized with the inaugural NCWIT Extension Services Transformation (NEXT) Award in 2015 for our efforts to increase the participation of women in undergraduate computing. At our 2015 graduation ceremony, we granted roughly 1/3rd of our computer science bachelor's degrees to women — more than twice the national average.

ENGAGING UNDER-SERVED COMMUNITIES

We worked with Rainier Scholars, a local academic enrichment program, to design and implement a computer science course for eighth grade students of color. We co-founded the University's AccessComputing Alliance to enable students with disabilities to successfully pursue computer science degrees. And we established the Taskar Center for Accessible Technology, which engages faculty and students in the development of technology solutions for people with mobility impairments by working directly with users and caregivers.

NURTURING THE NEXT GENERATION OF SCIENTISTS AND ENGINEERS

Through our robust K-12 outreach program, DawgBytes ("A taste of CSE"), UW CSE works with teachers across the state to incorporate computer science into their classrooms and organizes campus activities to inspire the next generation of computer scientists and engineers.

INSPIRING STUDENTS

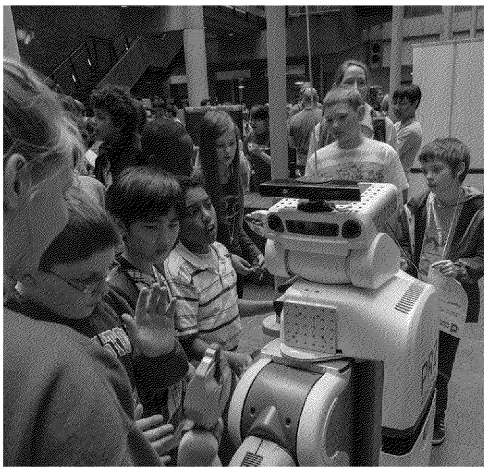
Our summer day camps provide students in grades three and up with an opportunity to explore the field of computing and to acquire programming skills. We offer both co-ed and girls' sessions, exposing several hundred campers each summer to the wonders of computer science through games, hands-on projects and interactions with UW CSE faculty and students.

EMPOWERING EDUCATORS

We invite middle and high school teachers to campus every summer for CS4HS, a professional development workshop that helps math and science educators to integrate computer science into their classroom teaching and build student interest in this rapidly growing field. Since CS4HS launched in 2007, nearly 500 Washington teachers have participated in these workshops.

Professor Ed Lazowska, Director of Student Services Crystal Eney, and lecturers Allison Obourn and Ruth Anderson accept the NEXT Award grand prize from NCWIT.

UW CSE organizes local activities to coincide with the annual Grace Hopper Celebration of Women in Computing and sends dozens of undergraduate and graduate students to the national conference each year.



Kids attending Engineering Discovery Days are greeted in the Allen Center by Hobbes, a PR2 robot from Professor Joshua Smith's lab.

THE CAMPAIGN FOR CSE

Computer science as a field has become a cornerstone of the modern university and of the modern world. At the University of Washington, computer science is impacting nearly every field: from sociology to astronomy, from psychology to economics, from oceanography to medicine, from neuroscience to law, from business to global health. Computer science is also transforming our industrial base and driving our state economy: in addition to home-grown companies of all shapes and sizes, more than 50 technology companies headquartered elsewhere have opened major R&D centers in and around Seattle — and a relationship with UW CSE is a major attraction for these companies.

UW CSE has a clear vision for the future, and we are marshaling the good will and resources of our friends, alumni and leaders in the innovation community to help us achieve that vision. Together, we can assure Washington's future position as a global center of innovation.

BUILDING FOR OUR FUTURE

We are forging a public-private partnership to assemble $110 million in funding for the construction of a new 130,000-square-foot building on the University of Washington's Seattle campus. This state-of-the-art facility will complement the Paul G. Allen Center for Computer Science & Engineering and accommodate UW CSE's recent and future growth. The Allen Center was a game-changer for our program, our university and our region when it came online in 2003. Twelve years later, we have a new opportunity to catapult UW CSE forward.

INVESTING IN OUR PEOPLE

We aim to grow UW CSE's endowment to $150 million, an increase of $100 million over the current level. This will provide approximately $6 million per year to recruit and retain world-class faculty, educate more Washington students regardless of their means, and attract the best and brightest graduate students and postdoctoral researchers to our state. When combined with increased physical capacity and planned strategic investments by the state, these resources will enable us to dramatically expand our research enterprise, double our degree production, and significantly increase education offerings to non-CSE majors — preparing more of Washington's students for Washington's leading-edge jobs, in an ever-broadening array of fields.

EXPANDING OUR LEADERSHIP

UW CSE has more than outgrown our space — we have outgrown our position in the university. We intend to turn a great Department of Computer Science & Engineering into a world-class School of Computer Science & Engineering. This strategic move will provide us with greater visibility and autonomy, and a level of flexibility that will enable us to be even more nimble and even more impactful in defining the forefront of our rapidly advancing field.

Our goals are both *unabashedly ambitious* and *attainable*. Join us! Contact Ed Lazowska to learn more and to join us in this vital effort to shape the future of UW CSE at lazowska@cs.washington.edu.

"What really sets UW's computer science program apart are the people – the faculty and the students. The Allen Center is a wonderful home for the program, but at the end of the day it's the excitement, intelligence and innovation of the men and women in this organization that make it what it is."

—Paul G. Allen, at the 2003 dedication of the building that bears his name

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Tuesday, March 14, 2017 9:44 AM
To: Steve Lombardi;Paul Allen;Bill Ayer;Joel Benoliel;Mike Bragg;Ana M. CAUCE;Tom Daniel;Paul Gilbert;Allen Israel;Jeremy Jaech;Bert Kolde;Connie Kravas;Ed Lazowska;Hank Levy;Judy Mahoney;Constance Rice;Franzi Roesner;Pat Shanahan;Rob Short;B Silverberg;Herb Simon;Charles Simonyi;Ben Slivka;Dave Stewart;Brad Smith;Austin Michael Wright-Pettibone;pamayer50@gmail.com;moebenoliel7@gmail.com;Jacquelyn Jaech;Alison Kolde;K. Kravas;Lyndsay Downs;rkatz@nephrology.washington.edu;Norm Rice;Emer Dooley;Lisa Simonyi
Subject: Fwd: Reception Photos

Photos from Thursday evening's Paul G. Allen School celebratory reception.

---------- Forwarded message ----------
From: **Peta Dyken** <petad@uw.edu>
Date: Tue, Mar 14, 2017 at 9:24 AM
Subject: Reception Photos
To: "JUDY K. MAHONEY" <jkm7@uw.edu>, Ed Lazowska <lazowska@cs.washington.edu>
Cc: Karine Raetzloff <kariner@uw.edu>, Annie Alldredge <alldra@uw.edu>

Good morning,
The photos from the Hill-Crest reception are now uploaded and available for viewing using the following link:

http://client.tara-brown.com/uwpaulgallenreception/

To log in, guests enter their email address and click through.
Please feel free to share/forward on to guests or others you feel are appropriate.

Best,
Peta D.

PETA DYKEN
President's Residence, Events

UW Tower Box 359520
4333 Brooklyn Avenue NE, S-4 Seattle, WA 98195-9520
206.685.6337 / mobile 206.310.4080
petad@uw.edu / washington.edu

UNIVERSITY of WASHINGTON

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Friday, March 10, 2017 9:11 AM
To: Kristin Osborne;Steve Lombardi;Paul Allen
Subject: GeekWire interview with Paul just posted

http://www.geekwire.com/2017/conversation-microsoft-co-founder-paul-allen-really-golden-age-whats-possible/

From: Ed Lazowska <lazowska@cs.washington.edu>
Sent: Monday, March 13, 2017 10:18 AM
To: Ana M. CAUCE;Pat Shanahan;Paul Allen;Brad Smith;Kristin Osborne;Steve Lombardi
Subject: Photos from GeekWire
Attachments: 20170309_Paul_Allen_UW_CSE_179.jpg

20170309_Paul_Allen_UW_CSE_185.jpg

Todd Bishop sent me two nice "toasting" photos. Attached. (One as an attachment, one as a Google Drive link.)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