



SEI-HCII Collaboration Explores Context-Aware Computing for Soldiers

featuring Dr. Anind Dey and Dr. Jeff Boleng interviewed by Suzanne Miller

Suzanne Miller: Welcome to the SEI podcast series, a production of the Carnegie Mellon University Software Engineering Institute. The SEI is a federally funded research and development center sponsored by the U.S. Department of Defense and operated by Carnegie Mellon University. A transcript of today's podcast is posted on the SEI website at sei.cmu.edu/podcasts.

My name is [Suzanne Miller](#). I am a principal researcher here at the SEI. Today, I am very pleased to introduce you to [Dr. Anind Dey](#), director of [CMU's Human Computer Interaction Institute](#) and [Dr. Jeff Boleng](#), a principal researcher in the SEI's Advance Mobile Systems Initiative. In today's podcast, we are going to be discussing their joint research into context-aware computing. These two researchers are collaborating to understand the mission, role, and task of individual dismounted soldiers and using context derived from sensors on them and their mobile devices to ensure that they have the information and support they need to optimize their mission. First, a little bit about our guest.

We are very fortunate to have Dr. Anind Dey with us today. Dr. Dey is an early pioneer in context-aware computing and authored one of the seminal papers in the field, titled [Understanding and Using Context](#). We have provided a link to that paper in our transcript, and I hope you will read it. In his research, Dr. Dey uses sensors and mobile technology to develop tools and techniques for understanding and modeling human behavior, primarily within the domains of health, automobiles, sustainability and education. One of his projects, called [dwellSense](#), use sensors to monitor daily activities of older people to detect physical or cognitive decline. The use of computer vision and other tools should detect behavior disorders, such as autism, automobile navigation systems that adapt to an individual's preferences, and automobile systems that convey navigation information through the steering wheel via sensory or touch feedback.

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Dr. Jeff Boleng is a senior member of the technical staff of the SEI on the [Advanced Mobile Systems team](#). His interests and experience span a wide gamut of computer science, from network protocols, operating systems, distributed computation, and embedded systems to numerical analysis, scientific computing, parallel processing, and concurrency. I am betting he uses all of these fields when he starts talking about context-aware computing. Welcome to you both.

Anind Dey: Thanks.

Jeff Boleng: Thanks.

Suzanne Miller: For those of you who haven't listened to our previous podcast on context-aware computing, let us start by having you give us a brief introduction to this topic, and also if you could define what is a dismounted soldier? Not everyone may be familiar with that term.

Jeff: I will take the dismounted soldier part. One of the reasons we focus on dismounted soldiers is if we can find a solution for the hardest problems, then it will move to other domains.

Suzanne: Dismounted in this case does not mean not riding a horse.

Jeff: Correct. It means not in a vehicle, carrying everything on their body that they need, all of the power, all of the compute, everything is person carried. I like to call it the first tactical mile. Because they are mobile, and they are dismounted, [with] limited battery life, limited computing, their bandwidth is disconnected and intermittent at times. So, sometimes you have to be able to work without a network connection or without a cloud connection. It is the most challenging environment we can conceive of. There is a need for much better automation support in that environment.

Suzanne: So, that is the need, one example of the need. So, the goal of context-aware computing is...?

Anind: To basically try and infer what that need is. So, to understand what the situation is for those military personnel, for those dismounted soldiers using all the sensing capability that they are carrying—in addition, if there happens to be sensors in the field that they can rely on—but, using that information to try and understand what the need is and then infer what the information is that they have to have.

Jeff: Just to add a little bit about the dismounted soldier: There is an interesting [DARPA](#) initiative going on that is about a year or year and a half old; it made the observation that the technology that is carried by soldiers into battle today has changed very little since the 60s.

Suzanne: Really?



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Jeff: Yes. The same firearms and almost the same radios that were being used in Vietnam are, by and large, the same ones that are issued to them today.

Suzanne: So, even the Defense—DARPA is the Defense Advanced Research Projects Agency—so, even that agency is seeing a disconnect in the technology available versus what is actually used?

Jeff: Yes. Well, specifically to the dismounted soldier. We put tons of technology into cockpits, tons of technology into tanks and wheeled vehicles. Once the person has got their boots on, and they are carrying what they can with them, they are carrying the same stuff that they carried in Vietnam, basically.

Suzanne: Except for the smartphone.

Jeff: Only in limited ways are they carrying smartphones now.

Suzanne: That is true.

Jeff: Soldiers are in fact carrying smartphones on an experimental basis in combat today. One of my goals is that the smartphone is not the piece of automation that the soldier carries; that it is a much smarter, better, form factor than that.

Suzanne: We are starting to see some of that come about in terms of different form factors and different ways of enabling computing without, as we call it, *the brick*.

Anind, in one of your papers, you defined *context-aware* as *environmental information that is part of an application's operating environment and that can be sensed by the application*. So, when we see things like [Google Glasses](#) and other wearable computing devices, how is the context-aware aspect fitting into that side of technology?

Anind: Right. So, both of those devices, or that collection of devices, whether it is a wearable smartwatch or the Google Glasses or a wearable or mobile phone, you can treat it as two different things. The first is a platform on which you can do a lot of mobile sensing about an individual or the environment. The second piece is an information consumption device. So, it is a place where applications can push information to individuals. So, if it is Google Glasses, then I can see it without having to pull the device out. If it is my wearable smartwatch, then I can just glance at it or I can get buzzed when there is information to be presented to me. But, it is an additional, more convenient platform other than having to pullout a computer or a phone.

Suzanne: So, there are situations where those kinds of devices would provide some advantage: when my hands are full and I can still consume data, but I don't actually have the ability to access a smartphone in a traditional way.

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Anind: Right. And, when time is of the essence, right? If I have to take the five seconds to pull up my phone, load the right app, or even if the information is there, I still have to pull it out because there is probably not easy access, very different than if information can just blast on my watch or my phone or my glasses.

Suzanne: I haven't tried Google Glasses yet, but I have a couple of friends that are very intrigued by them so... OK, but now, we are going to go to the joint research project.

Jeff: I have a little anecdote. I got one of those smartwatches that forwards when I get a text or an email, it forwards it to my wrist. Actually, one of the things that one of my friends does is when they know I am making an important presentation in front of the leaders of the SEI or something, he will send untoward things to my smartwatch, so that while I am talking I look down at them. It always makes me grin, and throws you off a little bit.

Suzanne: But, it also probably makes you relax. He is trying to make you relax.

Jeff: That's what it is.

Suzanne: That is what we are going to say.

Jeff: It is an interesting way to use those kinds of worn devices.

Suzanne: Actually, I would argue, that is a challenge of context-aware computing is, can the device actually know enough about your goal in your situation at the time to know, *Now is not the time to get one of those texts?*

Jeff: In this case, it doesn't know. Yes.

Suzanne: So, we haven't advanced that far yet.

OK. Let us go to your research project that you are working on together. Anind, you lead [CMU's Human-Computer Interaction Institute](#). Jeff, you work to help warfighters and emergency personnel operate at the tactical edge. We have defined that [the tactical edge] as environments constrained by limited communication, connectivity, storage availability, processing power, battery life; the dismounted soldier that you described fits that. Tell us about this current research project and how you came to collaborate on this work.

Jeff: About two years ago we got some funding to look at how can we more effectively share information in a group of soldiers. We developed a data model that would encapsulate the mission, role, and task of those soldiers. As we started sharing information, we started realizing that we can queue on the numerous sensors in mobile devices to do an even better job of delivering information.

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We were very naive when we started. It would be a menu press by one person would prompt another user, right? As we started to automate some of that with the sensor inputs, naturally we looked to Carnegie Mellon for people working in the space that have a lot of experience in doing that. We sought out Anind as a collaborator and his group because we were very naive going into it.

Suzanne: The human side. The SEI is really good on the computer side, but we need help on the human side because that is not a specialty area of many of our researchers.

Anind: Yes. So, we came in and we initially gave advice on just how the application should look and feel when the information is being presented to the individual soldiers or the group of soldiers. I think since then, the collaboration has really blossomed. So, we have gone off now and started looking at more of the technical side, in terms of frameworks that will support information provision based on context. We are starting to look at how to take individual context and turning it into a group context, and then, how to apply this in a variety of applications.

Suzanne: So, you are starting to build frameworks, which is one of the things that the SEI is actually very adept at. So, tell us about how you are field testing these frameworks. Because one of the things we know about frameworks is that good ideas don't always play out when you get them out in the field, especially when you have a lot of different things coming together in the framework.

Jeff: Sure. Yes. Our first attempt to do that was we went out to an exercise at [Camp Roberts](#) in California called [Joint Interoperability Field Experiments \(JIFX\)](#).

We basically just put handhelds in the hands of some soldiers, and we basically did some land navigation exercise and said, *Does this help you?* We got a lot of feedback there, but again, we were just starting.

We also came back to Pittsburgh and developed a relationship with a local Air Force Reserve Wing out at Pittsburgh Air Station. That has really led to some good collaborations. We created some scenarios. They have disaster scenarios on their base that they exercise to work through their procedures and their responses. We created an application that does a series of things to help them respond to those emergency situations and prompts them, delivers them information, and prompts them to do the right things. Again, we have gotten good feedback there.

Most recently, we wanted to focus on activity recognition. We tried to simulate things like being on patrol or taking cover from gunfire or something. It turns out, when you start to simulate those things, it doesn't work very well. We actually conceived of a very realistic scenario where the feedback is good. We use paintball now. We have done a couple of different paintball scenarios now.



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Suzanne: I bet you have lots of volunteers for that.

Jeff: We did. We had a ton of volunteers, actually, and the IRB [Institutional Review Board] approved it, so that was good.

Suzanne: Our Institutional Review Board is responsible for making sure we are responsible with our human subject research.

Jeff: Absolutely. Yes. So, we took some volunteers from the [911th Air Force Reserve Wing](#) and also some people from our group, and we went out and we created some paintball scenarios that simulated live action combat and put sensors on them and mobile devices on them and recorded the data streams from the sensors as they did that. We are in the process of distilling the data now.

Suzanne: So, the activity recognition that you are looking for is friend or foe, that sort of thing? What is the kind of level of detail are you looking for in terms of activity recognition?

Jeff: At the simplest, it would be individual activities like, *I am running. I am walking. I fell down, and I haven't moved for a while.* That could be important. All the way to, we are trying to really see if we can recognize group activities like, *This group of soldiers is on patrol, and they now came in contact with an enemy or they got ambushed. Or, They started firing or somebody started firing to them.* Those kinds of information cues are incredibly important. They are, of course, important for the squad that is being engaged, but they are incredibly important to get that information back to horizontal supporting forces or to a command post that can provide aid after an event like that.

Suzanne: OK. Or, even during, if it is fast enough. Even better.

Jeff: Yes. Absolutely.

Suzanne: What are your initial results? How did that go? I want to know about the paintball. How did that go?

Anind: We are very early in the phase of trying to understand the activities in the paintball, so we will have to report back to you in a later podcast.

Suzanne: That is an excuse for a future podcast. All right. I love it.

Jeff: We did some initial distillation for individual activity recognition though, and those results came out really well, 80 or 90 percent, something like that?

Anind: Yes.



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Suzanne: I assume you did something like video. So, you matched the actual things with what was predicted by the mobile sensors.

Jeff: It turns out that's a huge challenge. Yes.

Suzanne: Multi-perspective video, yes.

Jeff: And, providing ground truths for the training algorithms. It is just a lot of monotonous work.

Suzanne: Yes. That is a challenge. That is good. Jeff, we have interviewed several of your team members on the Advanced Mobile Systems initiative whose work seems to impact this. We talked a little bit about big data. I know some of the throwable wireless networks, is some other work that is going on. [James Edmondson](#) is doing some autonomous system stuff. [Soumya Simanta](#) is doing the [edge analytics](#). How are you interacting with some of that other research that is going on with your colleagues in the Mobile Systems?

Jeff: In our Mobile Systems group, we have got four primary focus areas that are complementary to each other. On the one sense, we have got the thing we call [cyber foraging, is the generic term which is really just compute offload](#), recognizing that a person can't carry a super computer but if there's a nearby computer, now that they can offload that data to sort of like moving the cloud as close to the edge of the battlefield as you can. In fact, it builds upon work from [Satya](#) and his group on campus called cloudlets. So, that is sort of the infrastructure piece of what we see as our edge of systems.

Marc Novakouski and I, with Anind's group, [have been working on a handheld piece, or on the soldier-carried piece, and also at the application and information delivery side](#).

James Edmondson's work is how can we have autonomous devices in the environment supporting and providing data, supporting the soldiers. The last piece, the edge analytics piece, is how can we use external information that is going in the world, how can you distill that in real time or near real time to also provide cues to that dismounted soldier?

Suzanne: All those have some effect on those context-aware kinds of research, and you affect them as well.

Jeff: We think that we have got the edge space fairly well covered, from a computing research area, with each of those four efforts.

Suzanne: So, have you looked into some of the things that I have seen out of the Human-Computer Interaction Institute, where you are looking at different ways of interacting with the



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computers with projected screens and using your hand as the device and some of those things? Are those at all on the radar of what you have been talking about in this area?

Anind: Yes. We certainly have discussed alternative modalities for both presenting information as well as providing input to the system. But, we are not actively working on any of those at this point.

Jeff: It is on the horizon though, because another engagement we have is with Special Operations Command. And, this alternative input and alternative information presentation is going to loom large in the next year to two.

Suzanne: Yes. We were talking about the inconvenience of smartphones. The one presentation I saw a couple of years ago, about some of the prototypes of using your hand as an input device, it was like, *Well, I should be able to count on having my hand there. There may be a glove on it.* I mean there are some modalities that are actually less risky if I lose my glasses, I lose my phone, that I can keep some of this with so...

Anind: Right. You want to have as much flexibility as possible. You want to be able to leverage whatever is around you. If there is a wall beside you, you want to be able to project onto that wall. If there is a table here, there's the table. That tremendous flexibility, I think, is going to be key, particularly since you don't know what situation you are going to be in.

Suzanne: I think that is something that may have some fun in the paintball world, for you as well as others. OK, so I have given you my idea where some of those researches should go. What are some of your ideas about where this collaboration should go?

Anind: What I really want to build is the ultimate personal assistant. People in AIM were thinking about this problem and working on this problem for years, but the ultimate personal assistant knows what you need before you need it.

It is not just even the information you need. It's how to present it to you so that it's not overwhelming and it's a way that you can take action on right away. The challenge that we are facing with context awareness is how to take, again, as we said before, this multitude of raw information sources and distill it into something that's actually useful.

Suzanne: There is useful. Now you are getting into not just the physical state of the human but also the emotional state.

Anind: Emotional and cognitive. Absolutely.

Suzanne: Right. Because the trick with the personal assistant is knowing when to speak up and when to wait 10 minutes until after some other event has gone on.

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Anind: Exactly.

Suzanne: So, that context is another really big challenge area.

Anind: Right. Just as an aside—I think it will play into the work that we do in our collaboration—we are currently doing some work in the automotive field where we are trying to determine automatically when a driver is most acceptable or susceptible to information coming from an external source. So, if the driver is white-knuckled and leaning forward, then we know that we should not provide any information unless it is life-critical information. But, if they are one-handed driving and leaning back, then we know that there is an opportunity to provide information.

We are trying to look at the value of the information coming in, the cost of presenting that information, and their current driving state, in order to figure out, *Does this information come through or not?* I think there is a great analogy to what we are doing in the automotive domain to this dismounted soldier.

Suzanne: Right. In that case, I am not going to tell them what the weather is going to be in 10 minutes if they are under fire right now. That is not really when they want to know that.

Anind: Right. That is why we need to understand both the individual activities as well as these group activities.

Suzanne: I think so. Well, I thank you both for joining us and talking about this wonderful collaboration. I love to see campus and the SEI get to do fun stuff together, and this certainly sounds like that that qualifies. I do want to thank you both for sharing that with us.

Jeff's research team, who is doing work in pervasive mobile computing, has information on their website at sei.cmu.edu/mobilecomputing/research. Anind has more information about [CMU's Human-Computer Interaction Institute](http://cmu.edu/hci) that he leads at hci.cmu.edu.

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