Pervasive Computing: Vision and Challenges

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Introduction

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

-Mark Weiser, The computer for the 21st century. **1999**

Introduction

- The main aim is to understand the challenges in ubiquitous and pervasive computing(UPC).

Some Background

- Pervasive computing represents a major step up in the thought of computing started by the fields of Distributed Systems and Mobile Computing.
- These fields are closely related.
- Some problems of pervasive computing can directly be mapped to these fields. Whereas for some the demands of pervasive computing necessitate the need for new solutions.

Distributed Systems

- The field of technology that deals with the intersection of personal computers with Local Area Networks

- This research domain deals with networks whether they be mobile or static, wired or wireless, sparse or pervasive.

Mobile Computing

- This domain deals with the problems of building a distributed system with mobile clients.
- Deals mainly with 4 main constraints:
  - unpredictable variation in network quality
  - lowered trust and robustness of mobile elements
  - limitations on local resources imposed by weight and size constraints
  - concern for battery power consumption.
- Still a developing field deals, still growing

Pervasive Computing

- An environment embedded with communication and computing capabilities yet integrated gracefully enough that it becomes invisible.

- Such a system must support mobility it subsumes the domain of Mobile Computing but goes further and incorporates 4 more research thrusts.

Pervasive Computing

Effective use of smart spaces

- This Topic deals with the idea of embedding computing resources into building infrastructure.

- This enables sensing and control of each other

Pervasive Computing

Invisibility

- The pursuit of pervasive computing technology which completely disappears from a user's consciousness.
- Or reasonable approximation to *minimal user distraction.*
- With a modicum of anticipation for important notifications.

Pervasive Computing

Localized Scalability

- In general scalability ignores physical distance
- In Pervasive computing the density of interactions has to fall of with distance.
- This is necessary because we need to remove needless interactions.

Pervasive Computing

Masking Uneven Conditioning

- Pervasive Computing needs to compensate for the varying condition of smartness.
- The Environment has to compensate for dumb spaces.
- Complete invisibility might be impossible but reduced variability is within reach

Example Scenarios

- We now sketch 2 hypothetical scenarios.
- The scenarios are out of reach just now but seem feasible in the near future.
- Although the examples use Aura as the pervasive computing system, these examples work in general too.

Example Scenarios

Scenario 1

Gate 23 Pittsburgh Airport

I want to upload documents. But the Bandwidth is terrible and my flight is about to leave

In comes **Project Aura**. Our Pervasive Computing Assistant

Example Scenarios

Scenario 1

Gate 23 Pittsburgh Airport

We can send messages from there. Meanwhile you should also prioritize your messages

Example Scenarios

Scenario 1

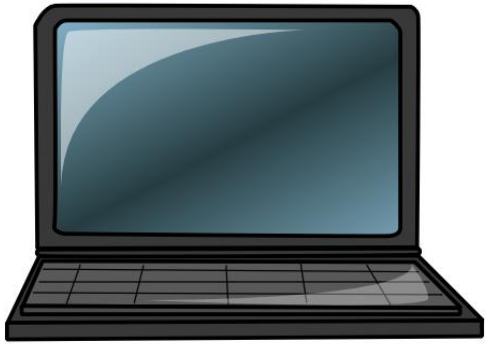
Gate 15 Pittsburgh Airport

Now we are almost done. Time to start walking back. The transmission should finish as we walk back.

Example Scenarios

Scenario 2

Fred's Office



He is working on his laptop on a presentation for a meeting

The meeting is 10 min away and it is time to leave

He grabs his palm wireless and walks out.

Example Scenarios

Scenario 2

Office Campus

Aura Transfers the work to his palmtop

He makes the final edits the work on his palmtop using voice input

Aura infers his destination from his calendar and location tracking

Example Scenarios

Scenario 2

Meeting Room

Aura Transfers the work to the meeting room projector

The Final edits are transferred just as Fred walks in

In the middle of the presentation Fred reaches a sensitive budget slide

Example Scenarios

Scenario 2

Meeting Room

Using the face recognition in the room, aura senses people not cleared for this information.

Aura warns Fred

Thus Fred skips this Slide

Example Scenarios

Missing capabilities

- These scenarios embody key areas of *pervasive computing*
- We see *proactivity.* How Aura is able to predict the time length of the process.
- In the first scenario we also see the importance of combining knowledge from two or more layers like a low level system layer like wireless congestion to a high level application layer like knowledge of boarding time.

Example Scenarios

Missing capabilities

- Scenario 2 shows ability to move execution across different platforms.

  Desktop → Handheld → Projector

- *Self-tuning* or the ability to adjust to different circumstances is also important. Keyboard Input on desktop → Voice Recognition on Handheld

Example Scenarios

Missing capabilities

- The most important concept shown here is that each of the individual technologies have been demonstrated.

- The major research is in the seamless integration of these technologies.

Drilling Down

User Intent

- Crucial for pervasive computing systems to track user intent.
- Today applications either fail in their attempt at tracking user intent or are just generic applications

Drilling Down

Cyber Foraging

- For sake of size and battery life computing power of mobile devices have to be compromised.
- But growing user expectations demand devices with computational power beyond mobile devices.
- Cyber Foraging*, "living of the land"* might be an effective way to deal with this problem
- The idea is to augment computing resources by scavenging of cheap wired hardware.

Drilling Down

Adaptation Strategy

- These are required when there is a mismatch in the supply and demand of resources.

- Three major strategies to deal with this

Drilling Down

Adaptation Strategy

1. Guide client to change application behavior to use less resources.
2. Client asks environment to guarantee a level of resource
3. Client advises user to take *corrective action* like Aura asks Jane to move to Gate 15

- Each of these strategies has equal importance and the important research is selecting the appropriate one.

Drilling Down

High-Level Energy Management

- Sophisticated pervasive computing technology increases energy demands.
- Growing consensus that battery technology and low power circuit design not enough to satisfy this requirement.
- Higher level layers of the system must become involved.
- Example energy aware memory management or energy aware adaptation

Drilling Down

Client Thickness

- How powerful does a mobile client need to be for a pervasive computing environment?
- A *thick* client refers to a powerful client and *thin* client is a minimal client.
- Thick clients are difficult to carry due to the them being large, heavy, power hungry.
- Improvements in technology reduce size but this changes the definition of a thin client.

Drilling Down

Client Thickness

- Minimal acceptable thinness is determined by the "*the worst-case environmental conditions under which the application must run satisfactorily.*"
- This means that the client should be thick enough to compensate for the worst case environment.

Drilling Down

Context Awareness

- A pervasive computing system to be truly invisible has to be aware of a users surroundings and situation and change its behavior accordingly
- One key challenge is collecting the user information needed to function in a context aware manner.

Drilling Down

Balancing Proactivity and Transparency

- One needs to be careful with Proactivity. A proactive system can very easily annoy a user.

- To strike the perfect balance, the system must be accurately aware of the context.

Drilling Down

Privacy and Trust

- The amount of information taken in by a pervasive system like location tracking, smart spaces etc. easily make it a privacy threat.

- There also needs to be an inherent 2 way trust mechanism between the user and the system.

Drilling Down

Impact on Layering

- There needs to be accurate and efficient information flow between layers for pervasive system.

- Deciding on how to decompose a complex software system into layers is still an art rather than science.

Current Scenario

- We now cover our expectation of such a system today
- I will sketch some normal expectations from my every day life.
- We will look at expectations from a human assistant and a computerized assistant like Aura.

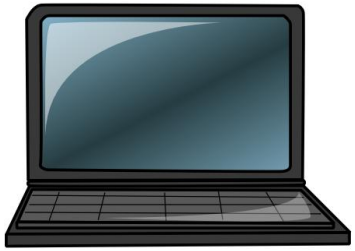
Current Scenario

- I will cover three scenarios
- The First is something that both of them can solve
- The Second that only works with a computerized assistant
- The Third is something that only a human assistant can solve

Current Scenario

- Then forgoing all technical terms we will look at what part of those scenarios is actually feasible today

- Then we will also have a small discussion on some challenges that we face



Monday 10 a.m.

I walk into college

I realize that two of my favourite TV Shows aired on Sunday

I need to stream these episodes to my Laptop

The Network is extremely busy right now

But later I have classes then I have to leave for home.

Now I need to leave this task to my assistant

Aura checks the listings of my favorite shows using Facebook data and Wikipedia.

It checks for download links

I realize that two of my favourite TV Shows aired on Sunday

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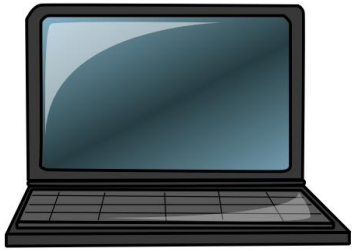

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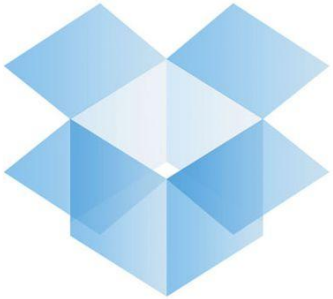
Current Scenario

- We now cover a scenario possible today by a computerized assistant.



Monday 3:45 p.m.

I walk into college Economics Class

My Phone and Tablet should automatically switch to silent

I start making notes on my tablet

I want these notes to sync on the cloud and access them on my laptop later

Current Scenario

- We now cover a scenario possible even today only by a computerized assistant.

Monday 5:30 p.m.

I remember about an important speech due tomorrow

But I have to stay up all night working on this presentation ☹

I can only jot down some important points for the report

I now ask my assistant to just draft these points into a presentation

I now ask my assistant to just draft these points into a presentation

Conclusion

Conclusion

- Collection of Data is not a problem
- At the time of writing this paper the major problem was integration of services as well as lack of capable hardware and sotware.
- None of us can imagine the Phones from a decade ago doing the stuff a Galaxy Nexus or Iphone 4s could do.

Conclusion

- Today we have capable hardware. We have more than capable Software.

- With Software companies focusing on integration of their ecosystems then the integration of services is not that big of a problem

Conclusion

- The major problem today is making a computer act like a human.
- Natural Language Processing and Semantic analysis are the major roadblocks at this point of time.
- Even the much publicized Siri is basically a fun toy rather than a usable system

Conclusion

- More importantly these systems are not everyday affordable.
- They cost a fortune to make.
- Last but not the least they make Skynet a very real threat.