

Assistive Technologies Based on Pervasive Computing

The National Institute of Standards and Technology (NIST) defines Pervasive Computing as a term that signifies several new elements of computing. One element involves pervasive computation - computers and sensors "everywhere" in devices, appliances, equipment, in homes, workplaces and factories, and in clothing. Another element involves pervasive communication - a high degree of communication among devices and sensors through a ubiquitous and secure network infrastructure with a wired core and wireless adjuncts that communicate with the core. Because computation will become so integrated into our lives and activities, natural forms of human-computer interaction, such as spoken dialogue with computers, will become more important."

The difficulty of achieving certain independent living skills, learning and working tasks, and everyday memory based events can overwhelm some individuals with disabilities when these situations are presented in an unordered or unassisted manner. Assistive technologies based on pervasive computing offer new possibilities for all individuals.

In the Assistive Technologies department we do not believe that we are unreasonable for wanting computers to help make independent living skills fairly ordinary, working and learning technologies easier, and individual memory skills or attention spans improved. Pervasive computing abilities for sensing, determining context-awareness, making correct inferences, and providing notifications to users of events or scheduled reminders should be the goal. Even modest gains in personal independence, working and learning abilities, or memory by using assistive technologies based on pervasive computing will enable an improved lifetime of learning, working, recreating, and socializing for all individuals.

The paper below outlines class projects for modeling and/or creating such devices in five basic areas involving independent living skills. They are:

- Housing & Work Environments
- Travel & Daily Task Management
- Educational & Classroom Activities
- Socialization & Recreation
- Shopping & Finances

The majority of the projects are focused on pervasive devices for living and working spaces listed under housing and work environments.

MOM Device	Potential Class Projects Source: Bill, Hal, John, Multiple Inputs	Independent Living Device	Work and Learning Aid	Scheduling & Notification
	Micro Omniscient Manager (MOM)			
A.1	MOM: Events Scheduler & Calendar			
A.2	MOM: Events / Performance Log			
	Housing & Work Environments			
1.	Automatic Door Entrance/Security			
2.	Notifications on Arrival/Departure			
3.	Environmental Control Subsystem			
4.	Pervasive Device Interface System			
4.1	-New Pervasive Computing Devices			
4.2	-Desktops, Portables, Tablets, PDAs			
4.3	-Telephones and Cellular Phones			
4.4	-Wireless and Wired Networking			
4.5	-Pervasive Computing Appl System			
5.	Temperature & Lighting			
5.1	-Temperature/Humidity Controls			
5.2	-Ambient/Artificial Lighting Control			
5.3	-Entertainment/Task Lighting			
6.	Wakeup/Wheelchair/Dressing Aids			
6.1	-Bedtime/Wakeup Alarms & Aids			
6.2	-Motorized Wheelchair Charging			
6.3	-Dressing Aids/Weather Notification			
7.	Clothing/Bedding/Room Storage			
8.	Bathing/Toileting/Grooming Aids			
9.	Meal Preparation/Food Storage			
10.	Adaptive Tableware/Utensil Storage			
11.	Kitchen, Appliances & Safety Aids			
12.	Daily Medication Storage/Metering			
13.	Kitchen/Housework Cleaning Aids			
14.	Laundry/Bedding Cleaning Aids			
	Travel & Daily Task Management			
15.	Appointments/Travel Arrangements			
16.	Work Tasks & Performance Monitor			
17.	Timed/Daily Medications Monitor			
18.	Hygiene - Urinary/Bowel Monitor			
19.	Medical - Overall Wellness Monitor			
20.	Daily Class, Work, & Meal Monitor based on Scheduled Events, Travel Arrangements & Required Materials			
21.	Transport/Travel Time Notifications			
22.	Updated Weather/Travel Notices			

23.	Accessible Bldg & Route Maps			
	Educational & Classroom Activities			
24.	Class Activity & Focus Reminders			
25.	Class Notes and Accommodations			
26.	Syllabus & Homework Task Monitor			
	Socialization & Recreation			
27.	Socialization & Recreation Activities			
	Shopping & Finances			
28.	Banking, Monthly Finances, Taxes			
29.	Shopping for Food/Clothing/Home			
30.	Fast Foods & Restaurant Meals			

Housing/Room Environments:

1. Automatic Door Entrance/Security System

Goal: Persons with and without disabilities spend a great amount of time fumbling with keys to open doors. For some individuals with disabilities, keys even after adaptations for accessible usage are extremely difficult or impossible to use. Lost keys may be expensive to replace as compared to an electronic security system where owner of the system may reset the electronic key identifier when it is lost or compromised. What is needed is an easy to use automatic door entrance based on a wireless key mechanism and a security system practical for all individuals to include people with moderate to severe disabilities.

Objective: To model a universal design for an automatic door entrance and omnipresent security system for an entrance to a building or living environment for persons with and without disabilities. As a starting point, consider exploring the use of radio frequency identification (RFID) systems with transponders embedded in wristbands, wallets, purses, jewelry, clothing, smartcards or other highly portable devices. Determine what automatic openers and electronic locking mechanisms might interface with such transponders or design such a device. Determine what frequency ranges and distances would be necessary to achieve a high degree of reliability so as to avoid interference when using RFID. Also, consider what methods might be used to ensure that users are actually wanting to unlock and/or open a door and the latency period needed for relocking a door should the door be automatically or manually opened/closed, and then relocked. Advanced modeling of an automatic door entrance or security system, may establish settings based on specific users and their needs (e.g., a user in a wheelchair) or preferences. The user may like to have the door locked or unlocked when entering specific locations, during certain hours of the day, or based on other conditions.

2. Notifications on Arrival/Departure

Goal: Determine what would be required to model, design, and or build a notification system and/or pervasive control mechanisms to assist users on a range of everyday tasks when arriving or departing work or living spaces.

2.1 Issue: People when arriving or departing work or living spaces often spend a great amount of time collecting information from computers, email, phones, etc. and changing or checking state of appliances, lighting, temperature, security systems, and other electronic devices.

Objective:

Modeling a notification system might require polling information from a wide range of computers, email, phones, appliances, lighting, temperature, security systems, etc., so as to provide appropriate notifications to specific users when arriving or departing work or a living space. The model might permit users to handle critical items and postpone items that can wait until later or be dismissed altogether. The system may

also permit the user on arrival or departure to set or change states of controlled devices based on predetermined or scheduled activities or to set controlled devices to a one-time setting, a new default setting, or establish a recurring setting. Advanced modeling may also make inferences from user patterns over time so as to suggest or make settings based on time of day, schedule, or other information. Lastly, polling information for a notification system implies that a pervasive networking system and a way to probe and alter a variety of disparate devices can be envisioned.

2.2 Issue: For persons with certain disabilities or simple memory issues suitable clothing may not be worn outside for forecast weather conditions and appropriate materials (e.g., portable computer, notebooks, lunch, wallet or purse, keys) may not be carried with them when traveling to/from work or classes. A notification system that prompts users only when needed regarding items they have forgotten or not considered when departing their living space.

Objective:

Modeling a notification system might range from simple verbal reminders of clothing and materials based on forecast weather conditions and a user's daily schedule. A more advanced system might pervasively identify the clothing being worn and the materials being carried by a user so to ensure that nothing is easily forgotten. For a more advanced system, one possible method might be a radio frequency identification (RFID) system with transponders embedded into articles of clothing and materials commonly used for work, classes, and items to transport a meal.

3. Environmental Control Subsystem

Goal: For individuals with disabilities many activities within a living space or office can be challenging. In these areas there exist many common devices needing to be controlled, but often the mechanisms to activate these devices are inappropriate for users, especially for users with moderate to severe physical disabilities. The goal is to model a universally accessible environmental control subsystem that can activate an entire range of new pervasive devices and computer systems (See **4. Pervasive Device Interface System**)

Objectives:

3.1 Model a system to exactly locate and isolate individual users anywhere in a living space or work location with the goal of biometrically identifying the user by voice, RFID transponder, or other mechanism as authentication control for pervasive computing services.

3.2 Based on 3.1 user identification, model a control subsystem to isolate the exact spatial location of users requesting services in a living space or workplace. Then model how to target the speaker with an array of microphones that will optimize a user's voice qualities and cancel out unrelated noise for the purpose of speech recognition. For locations with an insufficient array of microphones, consider directing a user to suitable locations that can support speech recognition or consider using an alternative input device (See 3.4 Model a portable/wireless universal controller).

- 3.3** Based on 3.2 control subsystem use speech recognition to model voice commands for a wide range of environmental control devices and services (see 4. Pervasive Device Interface System). This command set should be capable of supporting independent living skills and give appropriate feedback for users with memory/cognitive issues.
- 3.4** For people without speech, model a portable/wireless universal controller and interface capable of managing a wide range of environmental control devices and services (see 4. Pervasive Device Interface System). Use a command set based on 3.3 voice commands and user identification based on 3.1.

4. Pervasive Device Interface System

Goal: To paraphrase NIST, pervasive computing is a term that signifies pervasive computation - computers and sensors "everywhere" in devices, appliances, equipment, in homes, workplaces and factories, and in clothing. Another element involves pervasive communication - a high degree of communication among devices and sensors through a network infrastructure with a wired core and wireless adjuncts that communicate with the core. Because computation will be integrated into our lives and activities using natural forms of human-computer interaction, such as spoken dialogue with computers, will become more important. The goal for the pervasive device interface system is to model these core elements. Listed below are five items that comprise the interface system:

- 4.1 New Pervasive Computing Devices**
- 4.2 Desktop Computers, Portables, Tablet PCs, and PDAs**
- 4.3 Telephones and Cellular Phones**
- 4.4 Wireless and Wired Networking**
- 4.5 Pervasive Computing Application System**

Objective: Identify in detail the items that might comprise a Pervasive Device Interface System and how such a system would work or be modeled. An example of some phone interface features that might be included (in 4.3 Telephones and Cellular Phones) for persons with moderate to severe physical disabilities:

- Voice-controlled dial/answering and conversing from anywhere in the house.
- Voice control of personal phonebook, general online phone directories, etc.
- An emergency phrase to summon help (dial 911, caregiver, etc).
- Use the phone to control or check lights, appliances, heating and cooling, etc.
- Use voice to check or alter security status of doors, windows, and alarm system.
- Voice or display telephone caller-ID information on TV or a computer screen in user-defined font size. Establish automatic responses for known callers and/or individual voice-mail boxes for members of a household.
- Auto-mute stereo/TV when on the phone, based on interface system inference.
- When someone presses doorbell, mute audio/TV, stop loud appliances such as a robotic vacuum cleaner, and answer door via intercom from phone.

5. Temperature, Lighting, and Entertainment Systems

Goal: To develop a voice activated temperature, lighting and entertainment system that learns by inference from the users daily schedule, national weather forecasts, sunrise/sunset tables, ambient lighting reading and outside temperatures, and user preferences to include entertainment (Sousa for breakfast and Brahms for bedtime).

Objectives:

5.1 Temperature/Humidity Controls

Model a voice activated, inference capable, temperature and/or humidity control system that takes into account national weather forecasts, actual weather conditions, users scheduled activities and actual activities of those residing in a living space or work place. Provide notifications of HVAC maintenance needs to repair service and owner, and lastly provide emergency alerts for extreme temperature variances to those residing in the living space or work place, especially when there is an HVAC failure. Unless notified otherwise, alert users when temperature setting or humidity controls are being changed based on inference. When users are not present, based on daily schedules or patterns of activity, set back thermostat for energy savings in living spaces, unused rooms, or work place and return to desired temperature levels in advance of users return.

5.2 Ambient/Artificial Lighting Controls

Model a voice activated, inference capable, ambient and artificial lighting control system that takes into account the ambient lighting levels outside due to cloud cover and sunrise/sunset tables. Provide notification should outside security or walkway lighting not come on at scheduled times. Provide emergency lighting when needed.

Based on ambient lighting conditions, outside temperature levels, and user preferences adjust window treatments to provide ambient light or a closed window treatment for privacy or for reasons of temperature change to improve insulation.

For inside lighting - track user movements and adjust lighting level and window treatments accordingly based on inference from prior user activities and light settings. Use a fail-safe approach for lighting when user has visual disability or neurological disability, which requires higher or lower lighting conditions. Let user with disability adjust lighting before making inferences. Should other users alter the lighting, return to fail-safe conditions or the preference of user with a disability when they enter a room – unless they normally alter lighting when another person is in the room.

5.3 Entertainment/Task Lighting Controls

Model a voice activated, inference capable, settings entertainment and task lighting. This modeling may be more difficult due to more variable patterns of when occupants entertain, perform work at home, or study, which may require task lighting. Should pattern be discernable, such as music with a meal or regular recording on VCR, DVR, or PVR for TV entertainment, then the control system should ask occupant(s) whether

they want show recorded or music. Information on TV broadcast schedules can be obtained from Internet websites.

6. Wakeup Alarm/ Wheelchair/ Dressing Aids

Goal: For user to achieve daily independent living skills with the assistance of specialized bedtime or wakeup alarm system and reminder to charge motorized wheelchair at nighttime that may be prescheduled by a caregiver, parent, or user.

6.1 Bedtime/Wakeup Alarms

Objectives:

The Bedtime/Wakeup Alarms should be modeled to:

- Caregiver, parent, or user programmed daily schedule provides notification of time for bed. Notifications become more persistent when ignored. **(MOM)**
- Caregiver, parent, or user programmed daily schedule sets off clock alarm. **(MOM)**
- Should individual not wake up and start daily tasks at assigned time then (bed pressure sensors) set off more aggressive environmental lighting and/or a bed shaker to wake the individual. Snooze alarm capability may be preset for more gradual wakeup routine that begins at an earlier time. **(MOM)**
- Temperature controlled environment, lighting, etc. would adjust for users needs ahead of waking. When fully awake the individual is reminded to engage in next activity, such as bathing, dressing, and breakfast. **(MOM)**

6.2 Motorized Wheelchair Charging

Objectives:

The Motorized Wheelchair Charging should be modeled to:

- Caregiver, parent, or user programmed daily schedule provides notification of motorized wheelchair charging at nighttime. Notifications become more persistent when ignored. **(MOM)**

6.3 Dressing Aids/Weather Notification

Objectives:

Dressing and storage would utilize pervasive computing application system to determine the forecasted weather conditions and scheduled activities for the day.

- Ensure that clothing, based on RFID, has been appropriately selected for forecasted weather conditions and scheduled activities for the day. **(MOM)**
- Potentially detect whether individual has bathed and performed other needed morning tasks by analyzing the pattern of bathroom usage.

7. Clothing, Bedding, Room Storage

Goal: For user to achieve daily independent living skills with the assistance of notification and reminders to only use clean clothes, change the bedding when soiled, and to store clothes in the proper room storage devices based on RFID transponders inventory of available clothes.

Objectives:

Model a system for a user that must be reminded to wear only clean clothes due to cognitive issues. **(MOM)** can also be used to schedule clothes to wear weekly and to notify the user to put them in the laundry for cleaning after usage. **Cleanliness Sensors** embedded in the bedding and/or clothes will also detect when bedding/clothes were last laundered and are soiled and not suitable for wearing. Bedding and clothing may also have RFID transponders for inventory and their general location.

8. Bathing/Toileting/Grooming Aids

9. Meal Preparation/Food Storage

Goal: For user to achieve daily independent living skills preparing foods that are nutritious, based on a scheduled menu, and the food has been safely stored in the proper location and prepared properly (that is, not leaving the food out to spoil, refrigerating foods properly, and putting leftovers in the refrigerator when the meal has been eaten.)

Objectives:

Model a meal preparation and food storage system for a user cognitive issues that must be reminded to store foods safely in the proper location. RFID transponders with temperature sensors could detect when cold storage foods have not been kept sufficiently cold by a grocery store or the user. **(MOM)** could also be used to remind the user of what food to prepare and eat daily so that the use could follow a weekly menu not only for dietary reasons, but for money management purposes.

10. Adaptive Tableware/Utensil Storage

11. Kitchen, Appliances & Safety Aids

12. Daily Medication Storage/Metering

Goal: Many individuals with memory/cognitive issues and physical disabilities are required to take a complex daily schedule of medications. Three goals exist. First, ordering medications from a pharmacy when needed. Second, it is important to safely store, prepare, and meter the proper dosages of daily medications usually in a portable pillbox. Third, to ensure the proper dosages are taken at the correct times, so as to not endanger a persons health

Objective:

The objective for storing, preparing and metering medication into a daily pillbox can be achieved by the designing an intelligent pill dispenser. Such a device will enable a user to transfer the proper dosage of medications from a long-term storage device to a portable carry-along medium. The intelligent pill dispenser should both remind the user when refills of a prescription are due, but also insure that the user leaves home their medications in a pillbox with an RFID transponder. Additionally, the pillbox should be capable of reminding the user to take medications at a certain time, and verifying that the medications have actually been taken (a simple alarm when medications are due is not sufficient). Model and design both devices to help assist of a wide range of possible physical abilities, so that individuals with physical disabilities as well as memory/cognitive issues will be able to utilize the devices.

13. Kitchen/Housework Cleaning Aids

14. Laundry/Bedding Cleaning Aids

Travel & Daily Task Monitoring:

15. Appointments/Travel Arrangements

16. Work Tasks & Homework Monitor

17. Timed/Daily Medications Monitor

18. Hygiene - Urinary/Bowel Monitor

Goal: Provide notification or reminder for periodic/timed urinary and voiding activities for persons that lack bladder or bowel sensation.

Regular voiding of the bladder and bowel for persons lacking sensation is critical not only for health reasons, but to avoid embarrassment. For those who cannot sense the need to void, having a reminder is needed. Alarms can notify when wetting has already occurred, but a reminder system would help ensure consistent voiding and permit trend analysis that would infer a pattern should voiding not have been possible. The reminder could be in the form of a tone, vibration, or readout. The reminder could also be adjustable for the user's schedule (e.g. academic and vocational activities, travel), modifying alerts based on scheduled activities and possibly used to record amounts voided for persons required to measure actual urinary output for medical reasons.

19. Medical - Overall Wellness Monitor

Goal: Provide a health monitoring system.

Objectives:

Sensors are needed to pickup biometrics used to determine one's health. The current popular reading would be temperature, heart rate, weight, and blood pressure. These measurements ideally need to be taken unobtrusively. Any other biometrics specific to a user's medical need might also need to be collected. **(MOM)** would collect and store this information for the user or a medical professional to review. **(MOM)** could alert either user or a medical professional in the case of the biometric reading being out of range and

considered dangerous for the user. This could be a single high/low reading or a suspicious trend that could be life or safety threatening. In extreme cases, Emergency Response (911) could be summoned.

20. Daily Class, Work, & Meal Monitor based on Scheduled Events, Travel Arrangements & Required Materials

21. Transport/Travel Time Notifications

22. Updated Weather/Travel Notices

Goal: Create a notification system to alert the user to hazardous weather conditions.

When weather takes a turn for the worst (e.g. icing, heavy rains, tornado or other high wind events), the user needs to know so he/she can make the necessary adjustments to schedule and transportation.

Weather conditions would be monitored by (MOM). (MOM) can then alert the user by phone, cell phone, email, pager, crawl band across the bottom of a computer screen as to significant changes that would require action. Community alerts (such as BlacksburgAlert@blacksburg.gov) could be displayed on similar devices. When traveling, 511virginia.org or similar email alert service could be used to inform the user of potential congestion and hazardous situations on highways.

23. Accessible Bldg & Route Maps

Class Activities & Monitoring:

24. Class Activity & Focus Reminders

25. Class Notes and Accommodations

26. Syllabus & Homework Assignments

Socialization/Recreation:

27. Socialization & Recreation Activities

Money/Finance Management:

28. Banking, Monthly Finances, Taxes

Goal: Provide a system that would assist a person with keeping track of expenditures, making payments, alerting to financial anomalies.

Writing checks from a writing-sensitive checkbook would automatically provide the user with account adjustments. The checkbook would be synchronized with the monthly statement through MOM. Alerts would be set for overages, underages and unusual activity. Purchases made with a credit or debit card would be tracked and reported to the user throughout the month and reconciled automatically. The user would be alerted of

discrepancies that automatic reconciliation cannot resolve. All monthly utilities transactions will be automatically debited or charged to the appropriate credit card.

29. Shopping for Food/Clothing/Home

Goal: Create a system to aid in the inventory of food and provide an automated shopping list to the user.

Shopping for food:

The individual needs to know what items need to be purchased. This information is usually listed on a piece of paper and carried to the store. One scenario might be:

As items are removed from the refrigerator, the UPC labels are scanned. If the item is not returned to the refrigerator after a designated amount of time, then the refrigerator adds that item to the list. There is opportunity for creativity in determining how long an item is left out before it is added to the list. Some items require refrigeration while other items are chilled for convenience. MOM would need a database of the different allowable time for each item. How non-UPC coded items (vegetables, leftovers, medicines, etc.) are identified and tracked would have to be created. The shopping list would be available through a wireless connection to a PDA or tablet computer.

Note: Shopping is a complex activity involving transportation, communication, decision making, finances, delivery, and preparation for storage or assembly. The above scenario only deals with assembling the shopping list for food.

30. Fast Foods & Restaurant Meals

Micro Omniscient Manager (MOM) Pervasive Computing

Micro Omniscient Manager or MOM are a class of pervasive computing devices that can help take on many independent living skills that we take for granted and improve our reliability and efficiency in completing these tasks. The following assistive technologies may be used by anyone, but may be compensatory or even remedial for persons with disabilities, such as sensory loss or mobility issues. TBI (Traumatic Brain Injury), mental retardation, or lesser cognitive issues such as learning disabilities or simple forgetfulness. (Did I turn off the stove, lock the front door, or bring my lunch when I left my room or house this morning?)

The above devices a range of ideas for MOM pervasive computing modules that may be used in a variety of mobile and stationary devices to include: cellular phones, PDAs, tablet PC's, portable computers, desktop computers or more specialized items that may integrate devices into clothing, books, lunch/food containers, building materials for construction, etc. MOM has pervasive characteristics of being network or wirelessly programmable by an independent caregiver. It is capable of logging and recording trends in successful/failed completion of tasks for monitoring or improving remedial attempts at completing tasks. The items outlines above follow the pattern of tasks in a typical day for anyone, but will not be all inclusive of all items that may be integrated into MOM. Assistive Technologies given more time will provide a more comprehensive list of tasks that MOM can help achieve.