## Increasing an individual's quality of life via their intelligent home

The hypothesis of this project is: can an individual's quality of life be increased by integrating "intelligent technology" into their home environment. This hypothesis is very broad, and hence the researchers will investigate it with regard to various, potentially over-lapping, sub-sections of the population. In particular, the project will focus on sub-sections with health-care needs, because it is believed that these sub-sections will receive the greatest benefit from this enhanced approach to housing. Two research questions flow from this hypothesis: what are the health-care issues that could be improved via "intelligent housing", and what are the technological issues needing to be solved to allow "intelligent housing" to be constructed? While a small number of initiatives exist, outside Canada, which claim to investigate this area, none has the global vision of this area. Work tends to be in small areas with only a limited idea of how the individual pieces contribute towards a greater goal. This project has a very strong sense of what it is trying to attempt, and believes that without this global direction the other initiatives will fail to address the large important issues described within various parts of this proposal, and that with the correct global direction the sum of the parts will produce much greater rewards than the individual components. This new field has many parallels with the field of business process engineering, where many products fail due to only considering a sub-set of the issues, typically the technology subset. Successful projects and implementations only started flow when people started to realize that a holistic approach was essential. This holistic requirement also applies to the field of "smart housing"; if we genuinely want it to have benefit to the community rather than just technological interest. Having said this, much of the work outlined below is extremely important and contains a great deal of novelty within their individual topics.

### *Health-Care and Supportive housing*

To date, there has been little coordinated research on how "smart house" technologies can assist frail seniors in remaining at home, and/or reduce the costs experienced by their informal caregivers. Thus, the purpose of the proposed research is to determine the usefulness of a variety of residential technologies in helping seniors maintain their independence and in helping caregivers sustain their caring activities.

The overall design of the research is to focus on two groups of seniors. The first is seniors who are being discharged from an acute care setting with the potential for reduced ability to remain independent. An example is seniors who have had hip replacement surgery. This group may benefit from technologies that would help them become adapted to their reduced mobility. The second is seniors who have a chronic health problem such as dementia and who are receiving assistance from an informal caregiver living at a distance. Informal caregivers living at a distance from the cared-for senior are at high risk of caregiver burnout. Monitoring the cared-for senior for health and safety is one of the important tasks done by such caregivers. Devices such as floor sensors (to determine whether the senior has fallen) and access controls to ensure safety from intruders or to indicate elopement by a senior with dementia could reduce caregiver time spent commuting to monitor the senior.

For both samples, trials would consist of extended periods of residence within the 'smart house'. Samples of seniors being discharged from acute care would be recruited from acute care hospitals. Samples of seniors being cared for by informal caregivers at a distance could be recruited through dementia diagnosis clinics or through request from caregivers for respite.

Limited amounts of clinical and health service research has been conducted upon seniors (with complex health problems) in controlled environments such as that represented by the "smart house". For example, it is known that night vision of the aged is poor but there is very little information regarding the optimum level of lighting after wakening or for night activities. Falling is a major issue for older persons; and it results in injuries, disabilities and additional health care costs. For those with dementing illnesses, safety is the key issue during performance of the

activities of daily living (ADL). It is vital for us to be able to monitor where patients would fall during ADL. Patients and caregivers activities would be monitored and data will be collected in the following conditions.

Projects would concentrate on sub-populations, with a view to collecting scientific data about their conditions and the impact of technology upon their life styles. For example:

- Persons with stable chronic disability following a stroke and their caregivers: to research optimum models, types and location of various sensors for such patients (these patients may have neglect, hemiplegia, aphasia and judgment problems); to research pattern of movements during the ambulation, use of wheel chairs or canes on various type of floor material; to research caregivers support through e-health technology; to monitor frequencies and location of the falls; to evaluate the value of smart appliances for stroke patients and caregivers; to evaluate information and communication technology set up for Tele-homecare; to evaluate technology interface for Tele-homecare staff and clients; to evaluate the most effective way of lighting the various part of the house; to modify or develop new technology to enhance comfort and convenience of stroke patients and caregivers; to evaluate the value of surveillance systems in assisting caregivers.
- Persons with Alzheimer's disease and their caregivers: to evaluate the effect of smart house (unfamiliar environment) on their ability to conduct self-care with and without prompting; to evaluate their ability to use unfamiliar equipment in the smart house; to evaluate and monitor persons with Alzheimer's disease movement pattern; to evaluate and monitor falls or wandering; to evaluate the type and model of sensors to monitor patients; to evaluate the effect of wall color for patients and care givers; to evaluate the value of proper lighting.

*Technology - Ubiquitous Computing*

The ubiquitous computing infrastructure is viewed as the backbone of the "intelligence" within the house. In common with all ubiquitous computing systems, the primary components with this system will be: the array of sensors, the communication infrastructure and the software control (based upon software agents) infrastructure. Again, it is considered essential that this topic is investigated holistically.

*Sensor design:* The focus of research here will be development of (micro)-sensors and sensor arrays using smart materials, e.g. piezoelectric materials, magnetostrictive materials and shape memory alloys (SMAs). In particular, SMAs are a class of smart materials that are attractive candidates for sensing and actuating applications primarily because of their extraordinarily high work output/volume ratio compared to other smart materials. SMAs undergo a solid-solid phase transformation when subjected to an appropriate regime of mechanical and thermal load, resulting in a macroscopic change in dimensions and shape; this change is recoverable by reversing the thermo mechanical loading and is known as a one-way shape memory effect. Due to this material feature, SMAs can be used as both a sensor and an actuator. A very recent development is an effort to incorporate SMAs in micro-electromechanical systems (MEMS) so that these materials can be used as integral parts of micro-sensors and actuators.

MEMS are an area of activity where some of the technology is mature enough for possible commercial applications to emerge. Some examples are micro-chemical analyzers, humidity and pressure sensors, MEMS for flow control, synthetic jet actuators and optical MEMS (for the next generation internet). Incorporating SMAs in MEMS is a relatively new effort in the research community; to the best of our knowledge, only one group (Prof. Greg Carman, Mechanical Engineering, University of California, Los Angeles) has successfully demonstrated the dynamic properties of SMA-based MEMS. Here, the focus will be to harness the sensing and actuation capabilities of smart materials to design and fabricate useful and economically viable micro-sensors and actuators.

*Commuincations:* Construction and use of an "intelligent house" offers extensive opportunities to analyze and verify the operation of wireless and wired home-based communication services.

While some of these are already widely explored, many of the issues have received little or no attention. It is proposed to investigate the following issues:

- Measurement of channel statistics in a residential environment: knowledge of the indoor wireless channel statistics is critical for enabling the design of efficient transmitters and receivers, as well as determining appropriate levels of signal power, data transfer rates, modulation techniques, and error control codes for the wireless links. Interference, channel distortion, and spectral limitations that arises as a result of equipment for the disabled (wheelchairs, IV stands, monitoring equipment, etc.) is of particular interest.
- Design, analysis, and verification of enhanced antennas for indoor wireless communications. Indoor wireless communications present the need for compact and rugged antennas. New antenna designs, optimized for desired data rates, frequency of operation, and spatial requirements, could be considered.
- Verification and analysis of operation of indoor wireless networks: wireless networking standards for home automation have recently been commercialized. Integration of one or more of these systems into the smart house would provide the opportunity to verify the operation of these systems, examine their limitations, and determine whether the standards are over-designed to meet typical requirements.
- Determination of effective communications wiring plans for "smart homes.": there exist performance/cost tradeoffs regarding wired and wireless infrastructure. Measurement and analysis of various wireless network configurations will allow for determination of appropriate network designs.
- Consideration of coordinating indoor communication systems with larger-scale communication systems: indoor wireless networks are local to the vicinity of the residence. There exist broader-scale networks, such as the cellular telephone network, fixed wireless networks, and satellite-based communication networks. The viability and usefulness of compatibility between these services for the purposes of health-care monitoring, the tracking of dementia patients, etc needs to be considered.

*Software Agents and their Engineering:* An embedded-agent can be considered the equivalent of supplying a friendly expert with a product. Embedded-agents for Intelligent Buildings pose a number of challenges both at the level of the design methodology as well as the resulting detailed implementation. Projects in this area will include:

- Architectures for large-scale agent systems for human inhabited environment: successful deployment of agent technology in residential/extended care environments requires the design of new architectures for these systems. A suitable architecture should be simple and flexible to provide efficient agent operation in real time. At the same time, it should be hierarchical and rigid to allow enforcement of rules and restrictions ensuring safety of the inhabitants of the building system. These contradictory requirements have to be resolved by designing a new architecture that will be shared by all agents in the system.
- Robust Decision and Control Structures for Learning Agents: to achieve life-long learning abilities, the agents need to be equipped with powerful mechanisms for learning and adaptation. Isolated use of some traditional learning systems is not possible due to high-expected lifespan of these agents. We intend to develop hybrid learning systems combining several learning and representation techniques in an emergent fashion. Such systems will apply different approaches based on their own maturity and on the amount of change necessary to adapt to a new situation or learn new behaviors. To cope with high levels of non-determinism (from such sources as interaction with unpredictable human users), robust behaviors will be designed and implemented capable of dealing with different types of uncertainty (e.g. probabilistic and fuzzy uncertainty) using advanced techniques for sensory and data fusion, and inference mechanisms based on techniques of computational intelligence.

- Automatic modeling of real-world objects, including individual householders: The problems here are: "the locating and extracting" of information essential for representation of personality and habits of an individual; development of systems that "follow and adopt to" individual's mood and behavior. The solutions, based on data mining and evolutionary techniques, will utilize: (1) clustering methods, classification tress and association discovery techniques for the classification and partition of important relationships among different attributes for various features belonging to an individual, this is an essential element in finding behavioral patterns of an individual; and (2) neuro-fuzzy and rule-based systems with learning and adaptation capabilities used to develop models of an individual's characteristics, this is essential for estimation and prediction of potential activities and forward planning.
- Investigation of framework characteristics for ubiquitous computing: Consider distributed and internet-based systems, which perhaps have the most in common with ubiquitous computing, here again, the largest impact is not from specific software engineering processes, but is from available software frameworks or 'toolkits', which allow the rapid construction and deployment of many of the systems in these areas. Hence, it is proposed that the construction of the ubiquitous computing infrastructure for the "smart house" should also be utilized as a software engineering study. Researchers would start by visiting the few genuine ubiquitous computing systems in existence today, to try to build up an initial picture of the functionality of the framework. (This approach has obviously parallels with the approach of Gamma, Helm, Johnson and Vlissides deployed for their groundbreaking work on "design patterns". Unfortunately, in comparison to their work, the sample size here will be extremely small, and hence, additional work will be required to produce reliable answers.) This initial framework will subsequently be used as the basis of the smart house's software system. Undoubtedly, this initial framework will substantially evolve during the construction of the system, as the requirements of ubiquitous computing environment unfold. It is believed that such close involvement in the construction of a system is a necessary component in producing a truly useful and reliable artifact. By the end of the construction phase, it is expected to produce a stable framework, which can demonstrate that a large number of essential characteristics (or patterns) have been found for ubiquitous computing.
- Validation and Verification (V&V) issues for ubiquitous computing*:* it is hoped that the house will provide a test-bed for investigating validation and verification (V&V) issues for ubiquitous computing. The house will be used as an assessment vehicle to determine which, if any, V&V techniques, tools or approaches are useful within this environment. Further, it is planned to make this trial facility available to researchers worldwide to increase the use of this vehicle. In the long-term, it is expected that the facilities offered by this infrastructure will evolve into an internationally recognized "benchmarking" site for V&V activities in ubiquitous computing.

*Other technological areas*

The project also plans to investigate a number of additional areas, such as lighting systems, security systems, heating, ventilation and air conditioning, etc. For example, with regard to energy efficiency, the project currently anticipates undertaking two studies:
- *The Determination of the effectiveness of insulating shutters:* Exterior insulating shutters over time are not effective because of sealing problems. Interior shutters are superior and could be used to help reduce heat losses. However, their movement and positioning needs appropriate control to prevent window breakage due to thermal shock. The initiation of an opening or closing cycle would be based on measured exterior light levels; current internal heating levels; current and expected use of the house by the current inhabitants, etc.
- *A comparison of energy generation alternatives:* The energy use patterns can easily be monitored by instrumenting each appliance. Natural gas and electricity are natural choices for the main energy supply. The conversion of the chemical energy in the fuel to heat space and warm water can be done by conventional means or by use of a total energy system such as a Volvo Penta system. With this system, the fuel is used to power a small internal combustion engine,

which in turn drives a generator for electrical energy production. Waste heat from the coolant and the exhaust are used to heat water for domestic use and space heating. Excess electricity is fed back into the power grid or stored in batteries. At a future date, it is planned to substitute a fuel cell for the total energy system allowing for a direct comparison of the performance of two advanced systems.