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# The Smart Bathroom: UD through Integrating Physical and Digital Worlds

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**Abstract.** Although the abilities of people with disabilities are diverse, many accessible toilets are fixed. As a result, they can only support some abilities some of the time. The purpose of this project is to develop a smart bathroom capable of assessing an individual's abilities at any point in time and spontaneously adjusting supportive environmental features to accommodate those abilities. Specifically, the study will: 1) observe simulated toilet and shower/bathtub use in a state-of-the-art bathroom laboratory with embedded sensors and automated adjustment of fixtures and hardware; 2) develop algorithms that predict support needs; 3) integrate algorithms with the smart technologies to control the physical environment; and 4) evaluate the effectiveness of the smart bathroom system.

**Keywords:** smart bathroom technology, toilet transfers, bathing transfers

## Introduction

Historically, toilet accessibility has primarily consisted of a set of fixed grab bars and raised toilets that are based on the abilities of young male wheelchair users with good upper body strength [1]. However, as people with disabilities grow older, their functional limitations are exacerbated by age-related decrements. Increasingly, existing transfer solutions cannot compensate for age-related frailty. To compound the problem, functional abilities not only vary both across individuals, but also within individuals over time due to progressive chronic conditions, such as arthritis. As a result, fixed transfer systems are only able to support some abilities some of the time.

A number of studies have been undertaken to determine the optimum design for toilet transfer (e.g., [2-5]). However, only a few studies, have evaluated flexible systems. Most notable among these was the Friendly Rest Rooms for older adults project [6], which evaluated an adjustable height and tilt toilet. Although the adjustable toilet was effective, the lack of a similarly adjustable grab bar was problematic. Moreover, user control of the adjustments may not be effective for individuals who are not aware of the specific adjustments they need at a particular time.

To provide a more flexible environment that will accommodate a range of abilities at any time, the purpose of this 5-year project is to develop a smart, synchronously adjustable universal design bathroom capable of assessing an individual's abilities at any point in time and spontaneously adjusting supportive environmental features to accommodate those abilities. Using a state-of-the-art lab, the project will determine transfer needs; develop a model to predict needs; and integrate a predictive algorithm with physical products to meet the needs of anyone at any time.

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## 1. Development Plan

An existing bathroom in the Georgia Tech Aware Home Laboratory is being renovated to create a fully functional modular and motorized environment that will provide the flexibility for fixtures (i.e., toilet, tub and sink), supportive AT (e.g., grab bars) lighting and cabinetry to be rearranged or removed. An array of sensing technologies will be embedded in the environment (e.g., floor, walls, ceiling fixtures) to measure biomechanical data (e.g., gait, balance, posture, grip strength and speed, accuracy, and efficiency of movement); forces exerted on the toilet, bathtub, sink, and grab bars; and locations where fixtures and grab bars are used. A vision system (e.g. Kinect) and smart floor sensors will track movement and gait. In addition, motorized hardware will make adjustment to the various fixtures.

To develop the predictive algorithm, 25 individuals with a mobility limitation will participate in two test sessions at Time 1 ($T_{1)}$ and Time 2 ($T_2$). Functional measures of static and dynamic stability, posture, balance, gait speed, forward and side reaches, grip strength and range of motion will be taken using standardized instruments. Participants will transfer on/off or in/out of the fixtures. In $T_1$ subjects will perform the tasks with the fixtures set up in the same locations and positions (e.g., height, distance from walls) as in their own bathroom. At $T_2$, an occupational therapist (OT) will help subjects adjust the fixtures and grab bars to set up their optimum configuration. The configuration will then be tested, followed by a post-trial rating to determine if any of the dimensions require further adjustment. If so, the dimensions will be reset and the trial repeated. These procedures will be repeated until no adjustments are made.

## 2. Discussion

Given the general absence of integrative technologies in the design of bathroom products, we anticipate that the smart technologies developed in this project are at least 10 years from commercialization. However, within the 5-year project we expect to develop and market, a range of interim, "smarter" technologies that will provide a more universal design system through feedback that will enable users to adjust their transfer behaviors to optimize use of a fixed environment.

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