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Design Projects to Quantify the Health and Development of Autistic Children

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Mr. Brokesh joined the K-State BAE department in 2008 following a 24 year career as a senior design engineer working in the livestock, grain handling and ATV industries. Mr. Brokesh brings this industry experience to the classroom in order that students can better relate engineering concepts to practice. Mr. Brokesh is a licensed Professional Engineer in the state of Kansas.

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Design Projects to Quantify the Health and Development of Autistic Children

Abstract

Much remains to be learned about the roles that technology can play to (a) "quantify" the health status and development of an autistic child and (b) most effectively aid their classroom learning and their development in terms of activities of daily living. This work-in-progress paper provides an overview of senior design experiences in the Kansas State University (KSU) College of Engineering geared toward severely disabled children served by Heartspring in Wichita, KS. These projects engage about 30 engineering students/faculty and are supported with materials funding through the National Science Foundation's *General and Age-Related Disabilities Engineering* (*GARDE*) program. Projects are grouped into two thematic areas: (1) efforts that support the realization of a bed sensor suite for automated tracking of nighttime parameters that indicate child well being and (2) stand-alone design projects that address various facets of paraeducator ("para") and child well being and development. Students are encouraged to incorporate design mechanisms that allow device data to be uploaded to the Heartspring database that already contains these children's clinical records, individualized education plans (IEPs), and daily progress and behaviors as recorded on the iPod Touch 4 platforms carried by the paras that work one-on-one with these children throughout the day. Participation rates by students in broad curricula (i.e., biomedical and otherwise) imply that students in any area of engineering appreciate the opportunity to engage in a project with clear personal and societal benefit.

I. Introduction

About 1 in 6 children in the U.S. had a developmental disability during 2006–2008, ranging from mild disabilities such as speech and language impairments to serious disabilities such as cerebral palsy and autism. Autism is an increasingly diagnosed condition in children, where reported prevalence rates are now as high as one in 88 children.[1] Autism is a developmental disability that significantly affects verbal and nonverbal communication and social interaction. Other characteristics associated with autism are engagement in repetitive activities and stereotyped movements, resistance to environmental change or change in daily routines, and unusual responses to sensory experiences. Autistic children may also exhibit self-injurious behaviors or behaviors that can harm others. Recent studies estimate that the lifetime cost to care for an individual with an Autism Spectrum Disorder (ASD) is \$3.2M.[2]

Sleep disorders in children with an ASD are more prevalent (50-80%) than in age-matched neurotypical children (9-50%),[3, 4] and poor sleep quality in autistic children correlates with aggressive behavior, anxiety, and developmental regression.[3] Nocturnal polysomnography is the gold standard for diagnosing sleep disorders and assessing the impact of interventions. This technique involves continuous measurement of multiple neurophysiological and cardiorespiratory parameters, including electroencephalograms (EEGs), electrooculograms (EOGs), electromyograms (EMGs) of the chin and lower-limbs, electrocardiograms (ECGs), oronasal airflow, and arterial oxygen saturation.[5] A polysomnograph (PSG) is clinically used to diagnose sleep disorders like narcolepsy, periodic limb movement disorder, hypersomnia, and sleep apnea. While a PSG provides valuable data to characterize sleep quality, the signal-acquisition technologies are obtrusive and not easily tolerated by children.[6] The cost of the procedure and the necessary travel to a sleep laboratory also make it impractical for long-term sleep monitoring. For instance, biopotential measurements require wired electrodes in constant contact with the skin. Oxygen saturation is typically measured with a bulky finger-clip sensor, although reflectance-mode sensors are becoming available. ***An unmet need remains for the development of low-cost, unobtrusive technologies to quantitatively characterize nocturnal sleeping patterns of severely disabled children in their homes.***

The need to "quantify" the health status and development of severely disabled, autistic children is also important during the daytime, since a disabled child's progress is determined by data collected during structured settings as dictated by their IEP. However, working with autistic students while actively acquiring data is a challenge. To record data regarding student health, well being, or progress, a para must turn his or her attention from the student to a data sheet or a smart phone. This results in a loss of student attention, and valuable instructional time is spent redirecting the student back to the task. To avoid this, paras often store results in memory until a recording opportunity presents itself, which can lead to unreliable and invalid data. Further, collected data must be analyzed and shared with team members to be useful. This process can be arduous and time-consuming, requiring the teacher to spend time scoring data by hand and then entering these data into a spreadsheet. In such settings, where data are handled manually (still a reality in many facilities that work with disabled children), several weeks can elapse before a student's IEP is updated based on these numbers.

Clearly, much remains to be learned about the roles that technology can play to (a) quantify the health status and development of an autistic child and (b) most effectively aid their classroom learning and their development in terms of activities of daily living. From an engineering viewpoint, the needs of this population are tremendous and varied, providing a wide-open design space for students in all engineering curricula. This work-in-progress paper provides an overview of design experiences geared toward autistic children served by Heartspring in Wichita, KS.[7] These experiences are supported by multiple departments in the KSU College of Engineering: Electrical & Computer Engineering, Biological & Agricultural Engineering, Industrial & Manufacturing Systems Engineering, and Mechanical & Nuclear Engineering. Much of this work relates to senior design projects supported with materials funding through the National Science Foundation's General and Age-Related Disabilities Engineering (GARDE) program under grant CBET–1067740.

These projects, discussed in more detail in the paper, are intended to help paras and clinicians quantify the health and development of these children, leading to the identification of clearer outcomes that can be affiliated with the individualized education plan (IEP) managed for each child. To efficiently facilitate increases in child situational awareness, engineering students are encouraged to incorporate design mechanisms that will allow appropriate data to be uploaded to the Heartspring database that already contains these children's clinical records, IEPs, and daily progress and behaviors as recorded on the iPod Touch 4 platforms carried by the paras that work one-on-one with these children throughout the day.

II. Background

The NSF GARDE program[8] that supports these efforts under grant CBET–1067740 provides materials and supplies funds for undergraduate engineering design projects that aid persons with disabilities. The funding program expects investigators to work with an institution "providing care or education for individuals with disabilities," which in this case is Heartspring in Wichita, KS.[7] The Heartspring mission is to help children with special needs grow and learn on a path to a more independent life. Heartspring School serves severely disabled children with autism, mental retardation, Down syndrome, visual/hearing impairments, and behavior disorders. Most of these children have significant, multiple disabilities, meaning concomitant impairments (e.g., mental retardation-blindness, mental retardation-orthopedic impairment), the combination of which causes such severe educational needs that the student cannot be accommodated in special education programs solely for one of the impairments. Professionals available to Heartspring children include teachers, paraeducators, psychologists, medical staff, nutritionists, speech/language pathologists, physical and occupational therapists, a developmental pediatrician, and a child neurologist.

The current Heartspring enrollment is 52 students (ages 5–22) from 11 states. These students sleep in residential apartments on the Heartspring campus, and most students receive one-on-one paraeducator support throughout the day. About 96% of Heartspring students have a primary diagnosis of autism. 92% of Heartspring students work on functional activities of daily living such as bathing and teeth brushing, and 65% are non-verbal. Heartspring specialists use outcome-driven approaches consistent with a child's IEP: applied behavior analysis; medical treatment interventions; physical, occupational and speech therapies; music; adapted physical education; art; vocational training; functional academics; community-based learning; and the development of functional independence life skills. Psychologists perform routine and specialized assessments as well as participate in the development of customized IEPs. Medical staff and consultants provide primary care, and a speech language pathologist collaborates with each students' team to develop communication plans to support all areas of learning.

III. Methods

A. Emphasis Areas and Courses

Design projects are thematically grouped into two areas: (1) efforts that support the realization of a bed sensor suite for automated tracking of nighttime parameters that indicate child well-being and (2) stand-alone design projects that address various facets of paraeducator ("para") and child well being and development. These projects currently engage about 30 students and faculty in both formal design-project courses and informal special topics courses managed as independent design experiences:

- ***ECE 773 – Bioinstrumentation Design Laboratory.*** This 1-hour design experience is tightly coupled with *ECE 772 – Theory & Techniques of Bioinstrumentation*, a 2-hour lecture course that addresses various facets of biomedical instrumentation. ECE 773 projects currently focus on the elements of a bed sensor suite.
- ***ECE 690/890 – Wearable Medical Devices for Disabled Children.*** This informal, variable-credit 'special topics' course set was developed to support design experiences for the severely disabled children at Heartspring. These projects address various facets of child health, well-being, and development.
- ***BAE 536/636 – Biological Systems Engineering Senior Design I/II.*** These courses comprise the senior design core for the KSU BSE degree program. A paraeducator arm guard was the focus of the first project supported by this course set.

- ***IMSE 591/592 – Senior Design Projects I/II.*** These senior-design courses address ergonomics and process optimization as emphasized in the IMSE curriculum. The initial targets for this course set are surface computer games for educational and social training.
- ***ME 574/575 – Interdisciplinary Industrial Design Projects I/II.*** These courses comprise the senior design core for the KSU ME degree program. The initial project will be an adjustable mount (vertical and tilt) for a heavy 40" multi-touch surface computer.
- ***ECE 571 – Introduction to Biomedical Engineering*****.** While not a 'design' course per se, this course includes a two-week learning module dedicated to autism and individuals with special needs. The primary assignment for this module is a formal paper in IEEE format that proposes a design project to meet the needs of a severely disabled child. Such papers have formulated ideas for projects implemented in the design courses above.

B. Typical Project Constraints

Project descriptions vary from course to course depending on the project and the requirements imposed by the host curriculum. For the projects supported through ECE 690/890 and ECE 773, the following project constraints generally apply. Variations in these constraints are negotiated based on the type of design and the intended usage scenario.

Student Learning Objectives. At the completion of the project, each student should be able to do the following:

- Partition a medical instrumentation project into smaller, more manageable tasks.
- Relate the design of a bioinstrumentation system to a real-world context.
- Work more effectively with individuals having different areas of expertise.
- Match team members to project areas that maximize their interest and utilize their skills.
- Identify resources that facilitate biomedical product design.
- Document the development and performance of a medical instrumentation system.

Project Requirements. Prior to the completion of the semester, each team will develop a sensor-based system that acquires, processes, and displays data relevant to a real-world monitoring scenario. Each instrumentation system should start with the following design elements, but deviation from these requirements is negotiable. Interaction with clinicians or engineers from industry is encouraged.

Design Elements

- One or more sensors
- Signal conditioning circuitry and processing algorithms
- Computer-based data acquisition
- Graphical data display and user interface
- Strong design component

C. Bed Sensor Suite

In the *Introduction*, the authors noted that an unmet need remains for the development of low-cost, unobtrusive technologies to quantitatively characterize nocturnal sleeping patterns of severely disabled children in their homes. To meet that thematic need, a collection of design teams has been assembled to address the respective facets of a bed sensor suite as depicted in Figure 1 (refer to the bullet items below). This bed sensor suite is a proposed unobtrusive alternative to a traditional polysomnograph (PSG) as described in the *Introduction*. The suite will be managed through a multi-tabbed LabVIEW virtual instrument (VI) that resides on a computer at a central station manned by Heartspring residential apartment staff. Sensing devices located on or near the bed will acquire single-parameter and stream data, then upload those data to the VI for visualization and analysis.

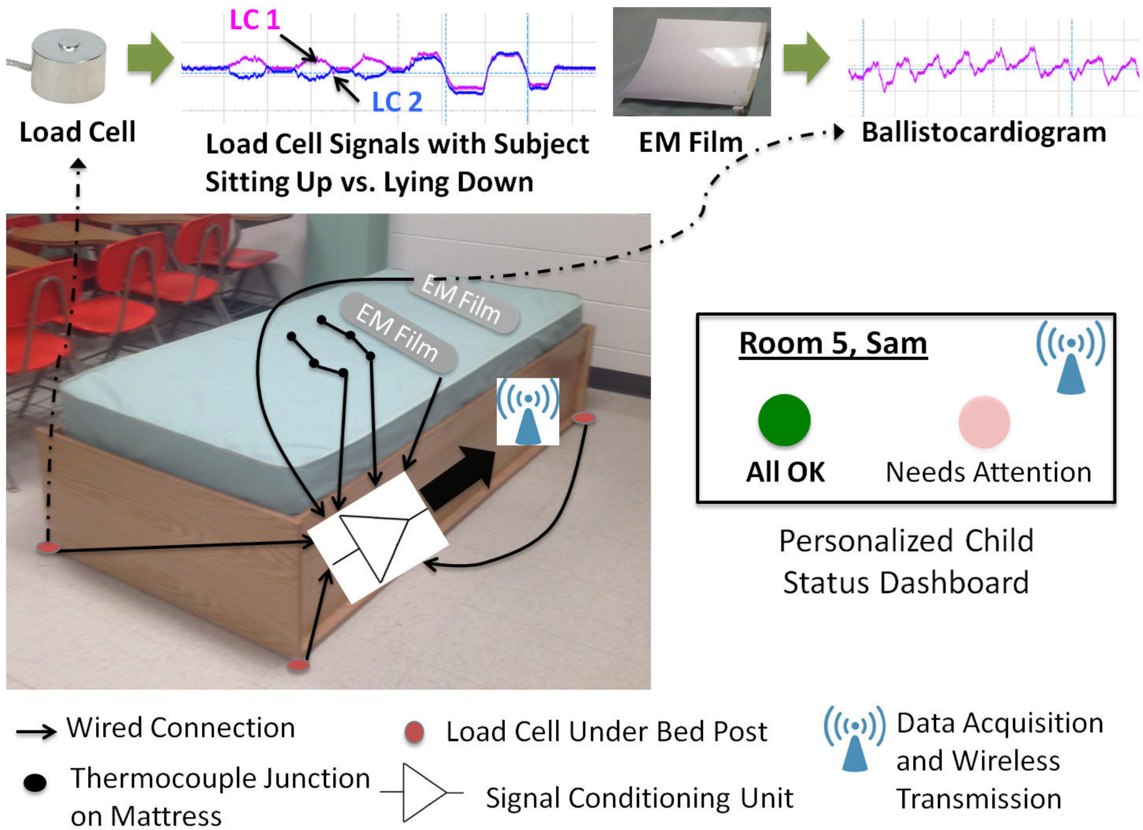

Figure 1. Depiction of a bed sensor suite and residential dashboard.

A bed sensor suite will provide the following data:

- Ballistocardiograms (BCGs) acquired with electromechanical force films placed inside or under the mattress (two EMFit L-Series electromechanical films, each 300 mm x 580 mm). These will provide heart rate, respiration rate, and movement data.
- Child movement signals (rolling around, in/out of bed, etc.) acquired with six load cells placed under the contact points of the bed frame (19 mm diameter, stainless-steel, miniature compression load cells manufactured by OMEGA Engineering, Part LCM302-200N). These signals may include physiological information similar to a BCG when the child is lying still.
- Body surface temperature and bed-wetting data acquired from an array of thermocouples arranged under the surface of the mattress (J-type thermocouples; TC direct; Part #201-144).
- Ambient temperature, humidity, pressure, and light levels acquired with an environmental sensor board (SEN-10586 USB Weatherboard from Sparkfun Electronics).
- Acoustic room noise, including child sounds, acquired with a nearby microphone.

A National Instruments data acquisition (DAQ) module (NI 9205-32, 32 channels, 250 kS/s) will collate these data and upload them through a wired or wireless link to the central station VI. The central station will present these data in summary form on a ‘dashboard’ that can take various forms, including a display as indicated in Figure 1 that simply indicates whether all is well, versus a complicated display that depicts current signals/data, sleep-quality metrics, and trends. Raw and processed data will be uploaded and stored in the central Heartspring database that also holds data entered by Heartspring paras through their iPod Touch units.

Note that the standard Heartspring bed in Figure 1 is a heavy, enclosed wooden structure. The empty space underneath the bed, inaccessible to the child, can hold the electronic subsystems. This design will allow the bed sensor suite to be moved from room to room within an apartment without each child realizing a change has occurred. When the collection of student designs is functional, the KSU teams will work to validate the data from the unobtrusive bed against a clinical PSG setup. While an ideal validation would involve data acquisition from Heartspring children, most of these severely disabled children are not well-suited to a wired PSG setup. Graduate students and/or neurotypical children may be the next best alternative.

Sleep quality metrics are an important research product. While total sleep, tossing/turning, REM cycles, bedwetting incidents, etc. should map to sleep quality (and by association child performance the next day), Heartspring staff note that these children do not function as expected based on experience will neurotypical kids.

D. Other Student Design Efforts

Other design efforts are underway that relate to daytime well being, assistance, and education:

- a **para-educator armguard** to protect a para from aggressive-child bites,
- a **behavior-counting glove** that a para can wear to tally child behaviors/events,
- a **self-abusive-behavior monitor** worn by a child (e.g., in a wristwatch form factor) that can automatically detect and count self-abuse events,
- a **gait analysis system** that can be worn by a child with a shoe-based orthosis,
- **textile-based antennas** for wearable devices embedded into clothing,
- a **musical toothbrush** that tracks brush movement/location and provides a child with positive feedback to reinforce desired brushing behavior, and
- **surface computer games** for child development and social interaction training.

For this target population, it is important for wearable devices or devices embedded in a child’s environment to be unobtrusive – essentially invisible – to avoid child/device interactions.

IV. Early Results and Discussion

A. Bed Sensor Suite

Film-Based Ballostocardiogram (BCG). A representative BCG acquired with the EMFit electromechanical film is illustrated in the upper right portion of Figure 1. With this film, a physical deformation creates a current which is then fed through an amplifier to create a voltage output. The size of the film relative to the bed is depicted in Figure 2, and the simple amplification and filter circuitry are depicted in Figure 3, representing a highpass filter with a cutoff frequency of 0.031 Hz. The output of the amplifier circuit is fed into LabVIEW, which either retains the respiration component (to yield a signal as depicted in Figure 4) or removes the respiration component (to yield a signal as depicted in Figure 5). Note that respiration rate and heart rate can easily be extracted from these respective signals.

Figure 2. EMFilm placed on the bed.

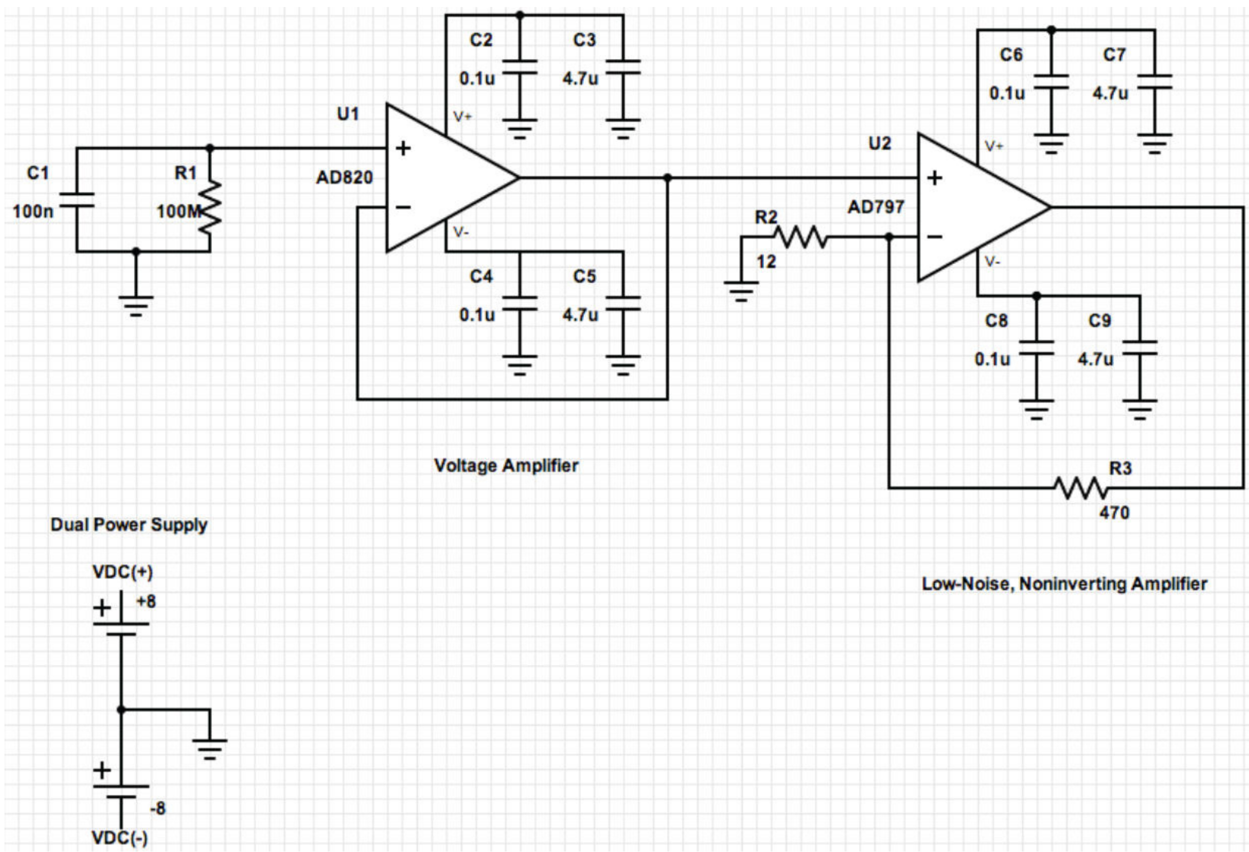

Figure 3. EMFilm circuitry.

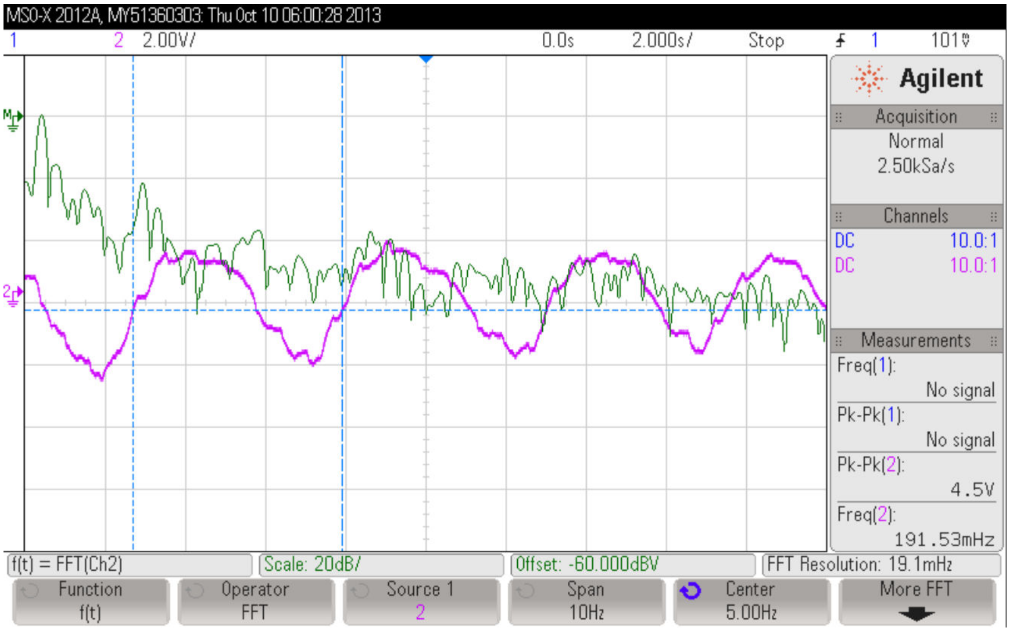

Figure 4. BCG that includes a respiration baseline.

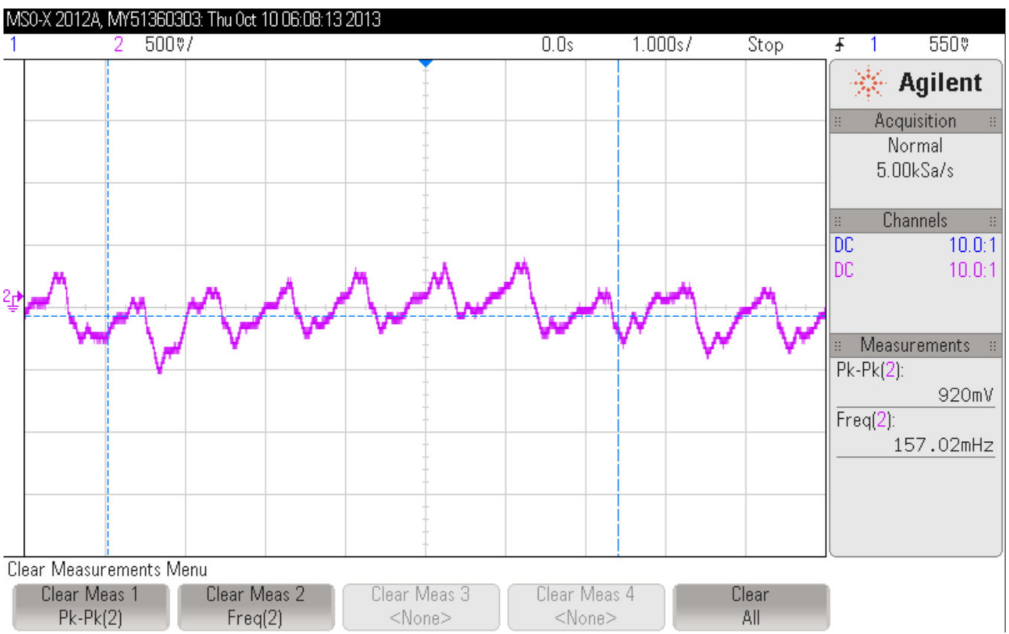

Figure 5. BCG with the respiration baseline removed.

Load Cell Data. Each load cell consists of a high quality strain gauge enclosed within a stainless steel casing and provides a voltage output proportional to applied force. Figure 6 depicts the simple signal conditioning circuitry used to amplify the signal from a load cell and filter out offsets (high pass filter with a corner frequency of 0.031 Hz) and noise (low pass filter with a corner frequency of 20 Hz) before the signal is digitized. Signals from such load cells provide two types of information – they capture the movement of the subject laying on the bed as well as some physiological information such as heart rate and respiratory rate, similar to a BCG.

Students evaluated the quality of the physiological data recorded by the load cells with a subject lying in various positions: supine, prone, left side, and right side. Signals with clearly distinguishable pulse rate and respiratory rate information (see Figure 7) were obtained for each position, except when the subject was lying on their right side. Representative load cell data illustrating subject movement were depicted in the upper center of Figure 1 (i.e., LC1 and LC2).

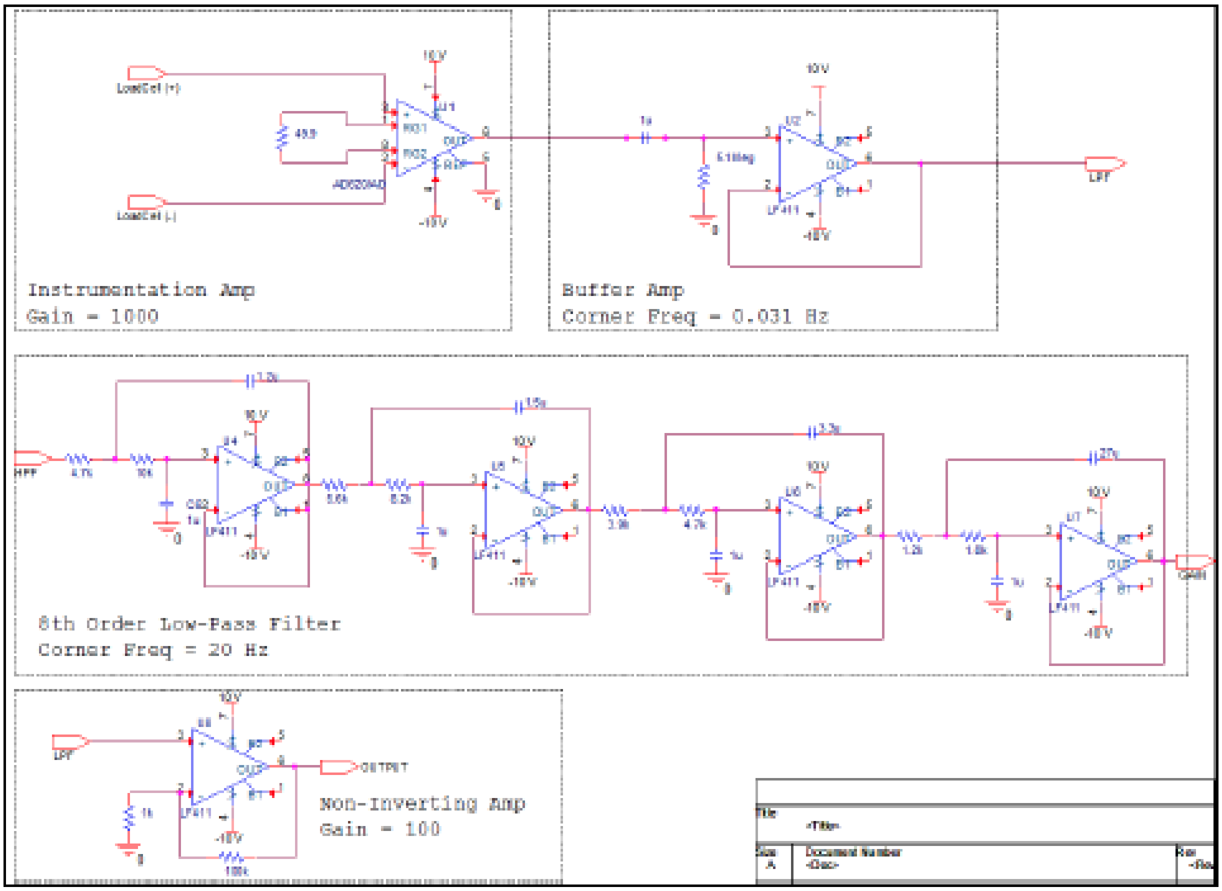

Figure 6. Signal conditioning circuitry to amplify and filter load cell signals prior to digitization.

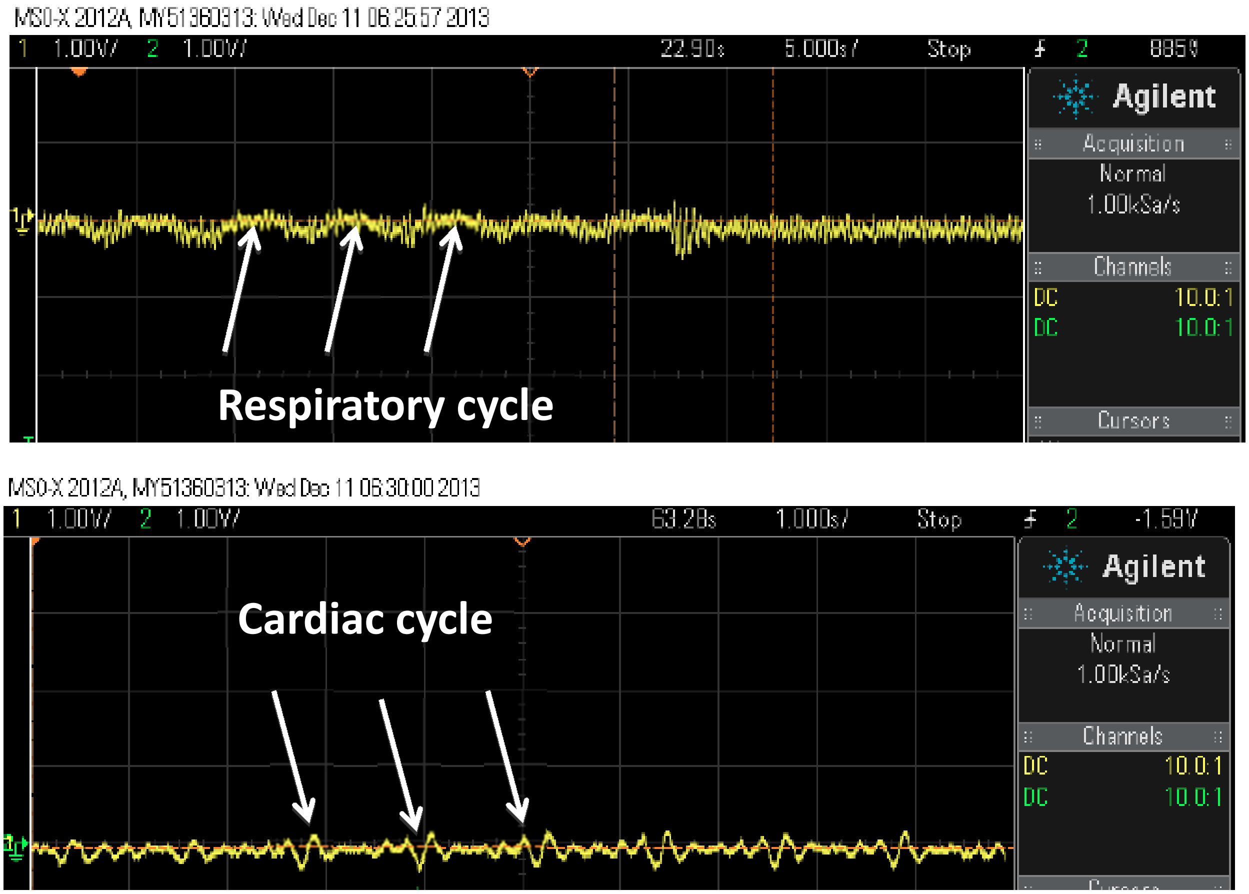

Figure 7. Physiological data captured by a load cell with a subject lying still on the bed. Such signals include information regarding the respiratory cycle (top) and cardiac cycle (bottom), similar to the BCG.

Thermocouple Data. Thermocouple junctions were positioned in such a way as to acquire a coarse map of subject surface temperature as well as detect changes in temperature close to the pelvic region, as depicted in Figure 8. It was hypothesized that bedwetting incidents may lead to small but rapid increases in temperature. Figure 9 illustrates temperature data measured with one of the thermocouples positioned on the mattress, covered by a bed sheet, and a subject lying on a diaper. At $t = 30$ seconds, the subject entered the bed, resulting in a temperature increase as the mattress equilibrated to the subject's body surface temperature. At $t = 1200$ seconds, a bolus of warm water (37 °C) was injected onto a diaper pad positioned between the subject and the bed sheet. This resulted in a rapid ~1.5 °C temperature rise, illustrating the potential for automatic detection of bedwetting incidents without the need for embedding sensors in the subject's diaper.

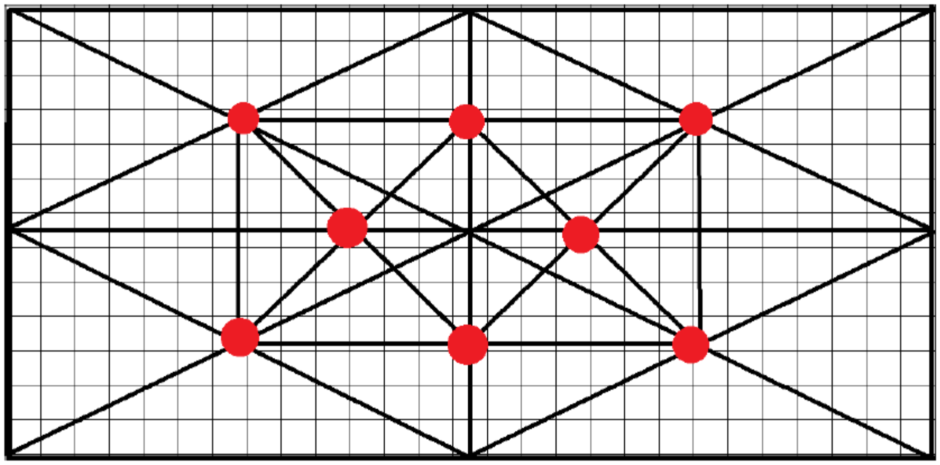

Figure 8. A depiction of thermocouple junctions (red circles) positioned at various locations on a mattress surface to measure body surface temperature and potentially identify bedwetting instances.

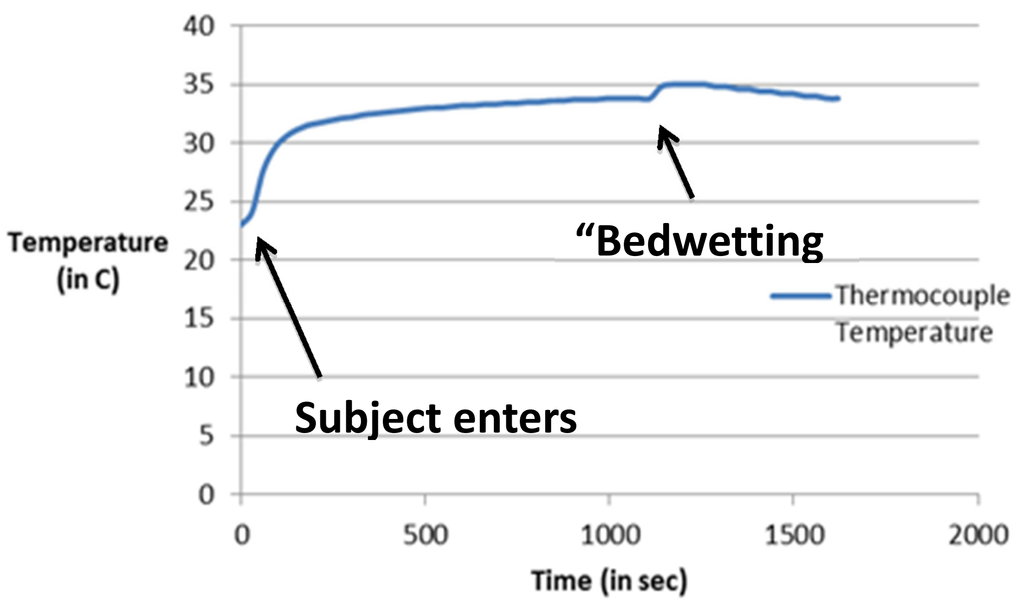

Figure 9. Temperature data recorded by a thermocouple positioned near the pelvic region, illustrating the potential for detecting bedwetting instances.

Early LabVIEW Interface. A LabVIEW virtual instrument (VI) was developed to record, collate, and display data gathered from the bed sensor suite. The VI was designed to display information at three levels of granularity, appropriate for providing insight into subject status to various Heartspring staff. The top level display indicates, with simple color indicators, a summary of the child's current status: "OK," "May need attention," and "Check on child immediately." It also lists any events that occurred on that night. This display level would be most suitable for paraprofessionals responsible for checking on the children during the night. The second interface level provides a statistical summary of various parameters that could be customized for each child. These may include heart rate, respiratory rate, bedroom environmental conditions, and a subjective sleep quality score. Such data may be appropriate for providing a snapshot of child status to clinical staff over a few nights. Finally, the most detailed interface provides access to the raw data recorded by each of the sensors. This may be of importance for clinical studies that track parameter changes or for the technical staff when making modifications to the system.

Summary Student design projects were undertaken to develop technologies for unobtrusive nighttime health status quantification for special-needs children. The targeted patient population requires that all technologies be unobtrusive yet still provide meaningful physiological and physical information. Results obtained so far indicate that the unobtrusive sensors explored in these projects may have promise for measuring subject pulse rate, respiratory rate, nighttime movement, bedroom environment, and bedwetting incidents. A parallel effort is underway to assess the quality of data recorded with the proposed bed sensor suite and compare these data against gold-standard polysomnography and other commercial devices currently available for measuring sleep quality. Undergraduate students have identified suitable commercial devices for this purpose and will compare sleep quality as measured with these systems to sleep quality as determined with the prototype sensor suite designed by their peers.

B. Other Student Design Efforts

Paraeducator Arm Guard. Heartspring students are low functioning, and aggression towards caregivers is fairly common. The arm protection device was designed to provide comfortable protection to the forearm and hand of a caregiver when confronted with biting and tearing. Bite injuries require a minimum of three visits to the doctor to complete the required blood tests, so these injuries are expensive and time consuming to treat. Severe tissue damage can be caused by a deep bite wound.

The arm guard concept and prototype are depicted in Figure 10 and Figure 11. The arm guard has three layers of material and extends from the base of the fingers to approximately 6 inches above the elbow. The internal layer in constant contact with the skin is a soft, moisture-wicking material. The middle layer is 100% Kevlar. The Kevlar extends from the back of the hand to the cuff of the guard and provides a high level of protection. An outer layer of denim provides additional protection and aesthetic appeal. Finger holes are formed from the moisture-wicking material to comfortably keep the guard in place on the hand. A cuff is located above the elbow to prevent the guard from slipping down the arm, and a Velcro strap is included on the cuff to increase the adaptability of the guard to different arm sizes.

Clinical testing of the first prototype at Heartspring indicated that additional protection and comfort were needed before the design would be accepted for use. The latest design has not been subjected to trials. From initial heat testing results, there is no significant difference in arm temperature while wearing the protective guard. However, additional heat testing is needed to verify these results. Further, additional puncture and tearing tests are needed to determine the level of protection provided. The cost of parts and material is about $11 per pair of arm guards. Including seamstress costs, it currently costs approximately $35 to produce a pair. This cost will be reduced if the guard can be manufactured in quantity.

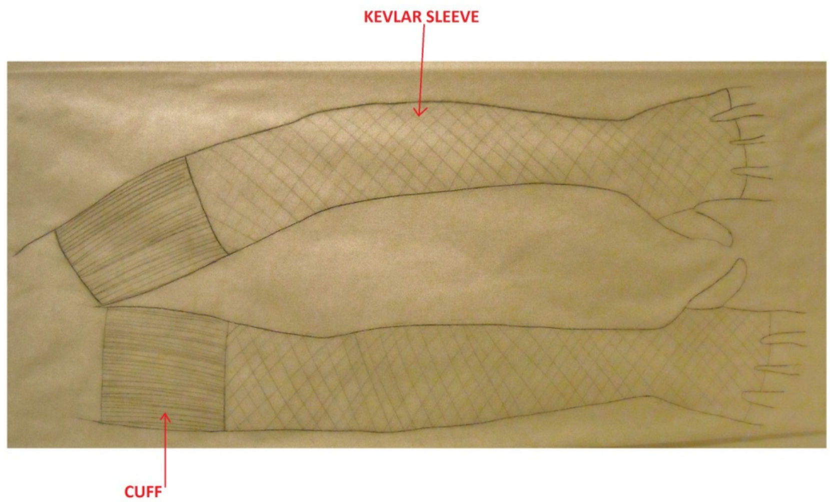

Figure 10. Original arm guard concept.

Figure 11. Original arm guard prototype.

Behavior-Counting Glove. One team continues to focus on a glove that could be worn by a paraeducator. If a child were to exhibit a behavior, the para could touch, e.g., a thumb to a finger, recording that event electronically rather than with a clipboard. Early versions of this glove are depicted in Figure 12, and the most recent version is depicted in Figure 13, where the conductive thread to each finger leads to a snap connector on the back of the hand. This project is ongoing, where a graphical display and wireless connectivity (e.g., between the glove and an iPhone) are being integrated into the system. Given a low-power Bluetooth link and the correct behavior-identification firmware, such a watch (e.g., a Texas Instruments Meta Watch) could automatically classify acquired accelerometer data and upload behavior counts to a para's iPod Touch, which would then forward these data to the Heartspring database. Such a capability would release the paraeducator from the need to record those events and allow them to focus on the child.

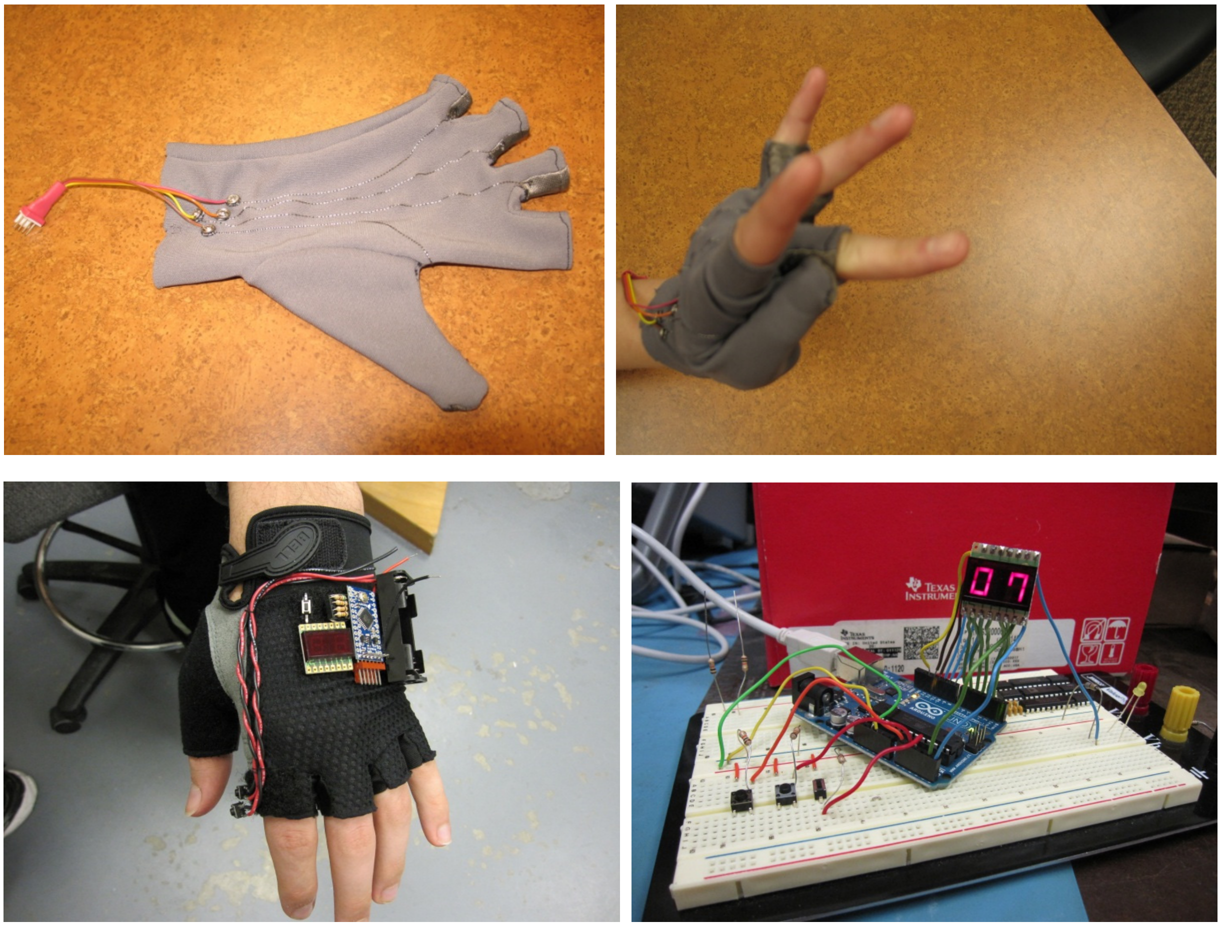

Figure 12. Early paraeducator glove concept.

Figure 13. Most recent paraeducator glove design.

Self-Abusive Behavior Monitor. Pending the availability of a Bluetooth-enabled MetaWatch, this team implemented a Texas Instruments ezChronos watch connected to a computer via a wireless dongle. These acceleration data were then imported into MATLAB for plotting and analysis. Illustrative data are depicted in Figure 14. Efforts are ongoing to employ machine learning methods to distinguish self-abusive events from normal movement.[9] The target block diagram for this work is illustrated in Figure 15.

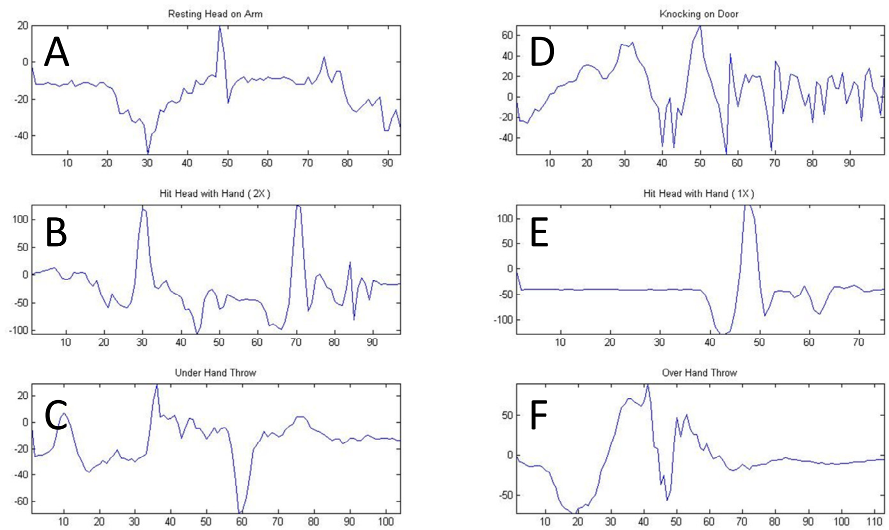

Figure 14. Illustrative signals from a wrist-worn accelerometer watch (TI ezChronos): resting head on arm (A), hand hitting head twice (B), underhand throw (C), knocking on door (D), hand hitting head once (E), and overhand throw (F).

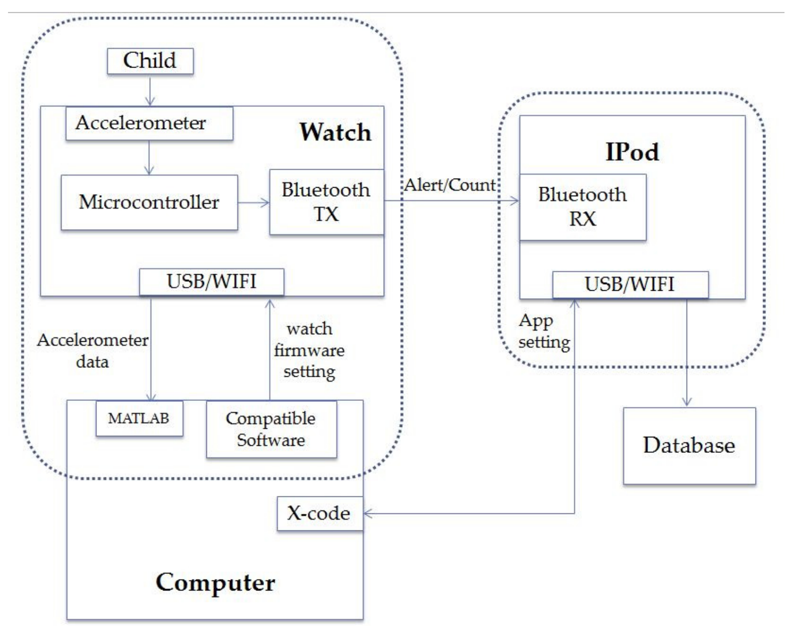

Figure 15. Target block diagram for the self-abuse indicator watch.

Surface Computer Games. The end goal of this effort is to develop multi-touch education and social-training games for the disabled children at Heartspring, where the intended platform is the Samsung SUR40 with Microsoft PixelSense technology. Given shipping damage to the intended platform, the design team moved ahead with development using a Microsoft Surface Pro tablet while those other hardware issues were being resolved. The functional template for a given game is illustrated in Figure 16. Generally speaking, a child will log into a game with para help and then be presented with a task consistent with their IEP. Upon completing each subtask, they will receive positive feedback from the game (in terms of audio encouragement and/or an image/video of a favorite character or object). When the game is complete, results will be uploaded to the Heartspring server and then mirrored back to the para's iPod Touch.

To date, a main user interface has been created to manage three games under development:

1. ***Sorting Shapes.*** The purpose of this game is to provide the child with shapes of varying color that need to be sorted. Depending on the game level, different numbers of shapes and colors are present. A timer starts when the child touches the first shape. If a shape is moved to the correct area, it disappears. Otherwise, it is returned to the game area. Positive reinforcement is associated with all player moves. Data collected include completion time, the number of touches required to complete the game, and the relative number of wrong placements.
2. ***What Doesn't Belong?*** Four pictures are provided, and the user is asked to select the image that does not belong based on characteristics that the other three images share. Categories to date include household/everyday items, foods, colors, and a random mixture of the three. Data collected include completion time, the relative number of incorrect attempts, and the category attempted.
3. ***Game of Emotions.*** The goal of this game is to teach appropriate emotions through recognized facial expressions. First, an event and its corresponding emotion are illustrated through an animated clip. The child is then asked to choose a facial expression that corresponds to the clip. Data collected include the emotion of interest and the relative number of incorrect attempts for each emotion scenario before the child gets it right.

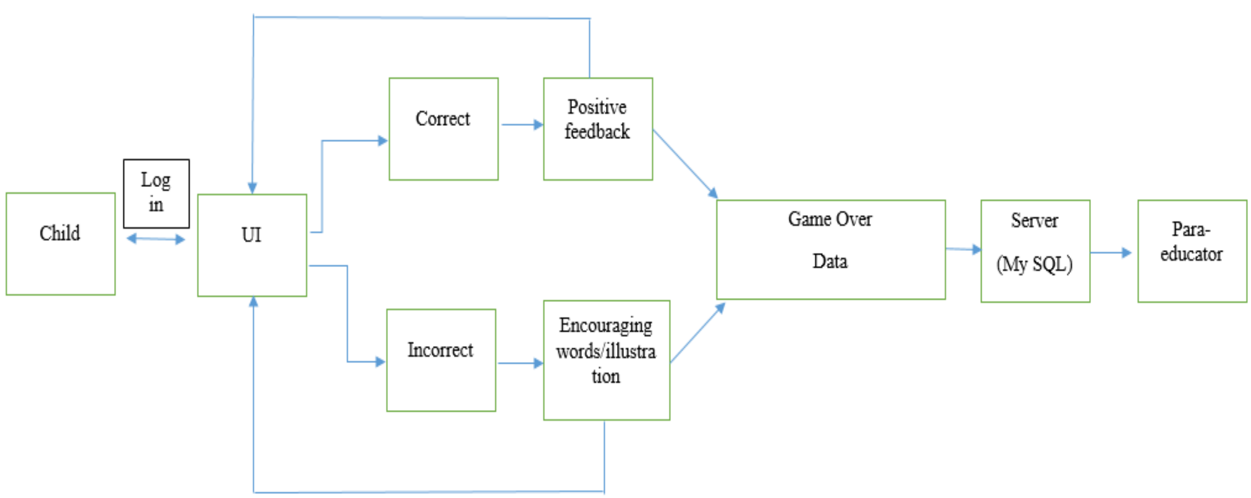

Figure 16. Functional template for a surface computer game.

V. Conclusion

This work-in-progress paper provided an overview of ongoing senior-design efforts in the KSU College of Engineering, where the goal is to provide technologies that can help to (a) "quantify" the health status and development of autistic children and (b) most effectively aid their classroom learning and their development in terms of activities of daily living. While multiple projects have been initiated, more effort needs to be invested to move these ideas into prototype designs that can be tested with their intended users at Heartspring. This speaks to a more aggressive development schedule, particularly in the Spring semester of each academic year, implying the need to move toward a two-semester expectation for every design that is initiated.

The needs of this disabled population are tremendous and varied, providing a wide-open design space for students in all engineering curricula. Further, severely disabled, autistic children are underrepresented in the engineering design space, partly because this population does not offer a large enough market presence to entice broad industry design participation. Many such projects are, by nature, "one of" designs. These realities offer opportunities for engaging design work at the university level, and participation rates by KSU engineering students in broad curricula (i.e., biomedical and otherwise) imply that students in any area of engineering appreciate the opportunity to engage in a project with clear and immediate societal benefit.

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