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Developing Smart Home Technology for People with Dementia

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People with dementia almost overwhelmingly wish to stay in their own homes for as long as possible. This is where their memories are and where they feel most secure. There is an important role for assistive technology to help them to achieve this aim and to support their personal carers who are often physically and emotionally drained by caring for someone with such cognitive problems.

At first sight it might seem inappropriate to use smart home technology to support people with dementia. After all they find it extremely hard to learn anything new and will become very confused and anxious about unknown pieces of equipment in their homes. The Gloucester smart home project has sought to apply this technology in a way that is invisible to the user, and to act in a way that emulates the interventions provided by a live-in carer. The house monitors the behaviour of the user and their interaction with domestic equipment, and provides support if necessary. Such support can be in the form of prompts and reminders, or by doing things like turning off taps if they are left on or providing lighting at night if the user gets out of bed. Unlike a carer the support is provided for 24 hours a day and without becoming tired or frustrated.

Several items have been installed in the house to deal with providing illumination, problems of wandering, problems with the use of the cooker, problems with the use of the bath or handbasins, problems of losing objects in the home, and others.

The solutions adopted will all be discussed together with the results of evaluations.

Integrating Community Equipment

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In 2000, an Audit Commission report⁽¹⁾ identified serious shortcomings in community equipment services. The services were fragmented, inadequately funded and managed and the service to clients was variable in the extreme. Around the same time, the NHS Plan⁽²⁾ was published and this included the aim of achieving a single, integrated community equipment service by 2004. Significant extra funding was promised for those organisations able to satisfy the conditions of joint planning and funding.

We are now halfway to the target date and some progress has been made, specifically in the setting-up of local implementation teams under a national framework. In those areas which already have joint loan equipment stores funded by both the NHS and social services, integration can only be improved by the local stakeholders talking together. The specific target of increasing by 50% the number of people benefiting from community equipment is a more ambitious aim which will require the release of the additional funding.

At present, the plans exclude wheelchair services and orthotics but do include telecare and electronic assistive technology. The latter two provide opportunities for clinical scientists who have the technical skills to assess, install and commission such equipment and the DoH Guide to Integrating Community Equipment⁽³⁾ refers specifically to this

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group of staff in the discussion on the use of the new investment.

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A Watched Pot Never Boils Dry: Temperature Sensing in the Kitchen

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Introduction Some people with dementia who wish to live independently may pose a risk to themselves and others from their absent-minded use of the kitchen cooker.

The authors have developed a system for monitoring the use of a cooker so that the risk of an adverse incident occurring can be reduced. This paper will describe the development of the part of the system primarily responsible for detecting the occurrence of unattended pans of water boiling dry.

Method Preliminary studies suggested that the temperature of the pan itself is a good indicator of the state of the contents of the pan.

Experiments were conducted using aluminium pans on a gas cooker to determine the optimum location(s) for pan contact temperature sensing methods including thermocouples and platinum resistance

temperature sensing elements. Similar experiments were also conducted with non-contact infrared radiation sensors.

Considerations such as ease of installation, non-invasiveness, reliability and repeatability of results led to a decision to use a non-contact sensing method using commercially available radiation thermometers. Two infrared sensors are required to monitor a cooker hob with four rings.

A simple, microprocessor-based algorithm was then developed to detect boil-dry events with the minimum of false positive triggers. The outputs from the sensors are processed by a microcontroller that calculates a running average temperature and triggers an electro-mechanical shut-off system in the event of a sustained positive increase in temperature gradient above a threshold temperature.

Results The entire system is undergoing long-term evaluation in the UK and Ireland as part of a research project funded by the European Commission. Preliminary results from this project will be presented if available.

A Test Rig for Metacarpophalangeal Prostheses Producing Failures Matching those seen in Vivo

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Introduction The replacement of diseased finger joints lacks the success achieved with hip and knee prostheses. Part of the reason for this is that test rigs for finger prostheses have not produced failure of the test prosthesis in a manner similar to that found in vivo [1]. In an attempt to improve upon this situation, a new test rig for metacarpophalangeal (MCP) prostheses was developed.

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Method The finger simulator aims to reproduce the natural biomechanics of the finger joints, therefore artificial 'tendons' are used to apply the load and motion seen by an MCP joint, while loading consists of a combination of dynamic flexion-extension together with a heavier, static 'pinch' load. Using this single-station machine, a size 2 Swanson prosthesis and two Sutter size 50 MCP prostheses were tested. Test loads were 10-15N dynamic and 100N static, a speed of 100 cycles per minute was employed and Ringer solution at 37°C was used as the lubricant.

Results All test prostheses failed due to fracture at the junction of the distal stem and hinge, a result which matches that seen in vivo [2, 3]. The small size 2 Swanson prosthesis failed in just under one million cycles of flexion-extension and just over 300 'pinch' loads, while the two much larger size 50 Sutter MCP prostheses lasted 5.3 and 10 million cycles of flexion-extension respectively.

Conclusion A simulator has been manufactured which has reproduced clinical type failures of two designs of MCP prosthesis. With such a device, new designs of finger prosthesis can be better tested in vitro.

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Defining the Neutral Zone of Intervertebral Joints Using a Robotic Testing Facility

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Introduction The Neutral Zone is defined as a region of no or little resistance to motion in the middle of an intervertebral joint's range of movement. Previous studies have used quasi-static loading regimes that do not model physiological activity [1]. The aim of the present study was to assess experimentally the existence of the Neutral Zone of intervertebral joints during physiological movements of flexion/extension, lateral bending and axial rotation simulated using a robotic testing facility. Sheep intervertebral joints were used as they have been shown to exhibit similar mechanical behaviour to human joints [2].

Methods Five spines from mature sheep were used. Three specimens were tested from each spine to simulate human L1/2, L3/4 and L4/5 intervertebral joints. The robotic facility enabled the motion controlled testing regime to be defined for each individual joint based on its geometry. The joints were tested by cycling through the full range of physiological movement in flexion/extension, lateral bending and axial rotation.

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Results A Neutral Zone was found to exist during dynamic movements only in flexion/extension. The results were equivocal for lateral bending and suggested that a Neutral Zone does not exist in axial rotation. The zygapophysial joints were shown to be significant in determining the mechanics of the intervertebral joints as their removal increased the Neutral Zone in all cases. A criterion for defining the size of the Neutral Zone was proposed.

Conclusion A Neutral Zone exists in flexion/extension during dynamic movements of intervertebral joints. This has important implications for the muscular control of the spine consisting of several intrinsically lax joints stacked on one another.

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Application of Size Correction Algorithms to Paediatric Bone Density Data

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Introduction Bone size is known to influence accuracy in bone density assessment, particularly when assessing children and adolescents. Algorithms to reduce this influence have been proposed [1,2], although there is currently no common approach.

Method Unselected patient data (Hologic QDR 2000 array scans, L1-4 and total body) relating to 75 girls

and 33 boys (median age 15.3, range 2.6-19.8 years) were analysed. All scans had been carried out in response to a clinical referral from a hospital consultant. Size correction algorithms included Bone Mineral Apparent Density [1] (BMAD) and Bone Mineral Density divided by the square root of body surface area [2] (BMD/rootBS) were used. Uncorrected and corrected patient results were plotted on a series of linear graphs each indicating a bone density related quantity on the vertical axis and age on the horizontal axis. For each graph normative data was also plotted indicating age related means and ranges. Size correction algorithms were judged according to the flatness of the proposed parameter with age (and therefore bone size), consistency of patient and normative data and clarity of information presented.

Results BMAD at the lumbar spine and BMD/root BS for total body gave superior results based upon flatness and consistency

Conclusion Based upon clarity of information presented, a series of graphs, incorporating both raw and size-adjusted patient data is proposed.

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Practical Experiences of Providing a Computer Access Assessment Service in the Former Northern Region

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Introduction The Regional Medical Physics Department has provided a Technical Aid Service (TAS) throughout the former Northern Region for over 20 years. In 1996 it was recognised that there was a need to extend TAS's remit to include assessments for computer access. This service was piloted for eight months before going live in August 1997; since its inception, almost 100 referrals have been completed.

The Service Referrals are received from Health Care Professionals in the former Northern Region. On receipt of the referral, a questionnaire is sent to the referrer for completion. When this is returned a visit is arranged and a visit protocol form is completed based on the questionnaire. The assessment visit is carried out and a report sent to the referrer and client. This may be followed by further visits.

Discussion The provision of this type of assessment service places specific demands on those involved. Factors that will be discussed include:

- ❑ Deciding on the remit of the service
- ❑ Managing the speed of technological change
- ❑ Use of assessment protocols
- ❑ Defining/deciding on roles
- ❑ Knowing the bounds of your expertise and working within these
- ❑ Assessment tools and tasks
- ❑ Common solutions
- ❑ Ensuring the client has confidence in the proposed solution

- ❑ Training
- ❑ Review and follow up

Orbital Floor Repairs – An Extension of our Existing Cranioplasty Service

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Introduction The medical imaging group at the joint UCL-UCLH Medical Physics and Bioengineering department successfully produces accurate titanium plates for the reconstruction of craniofacial and maxillofacial bony defects (over 250 in the last 10 years) from CT scans using computer-assisted design and manufacture methods. The improvement of CT scanner resolution now allows us to plan computer-assisted designed implants to repair complex orbital wall and floor defects. This paper relates our experience in developing these implants.

Methods The orbital defect was assessed on an interactive display showing simultaneously the patient's sagittal, coronal and transverse CT cross-sections and 3D reconstruction. The mirror-image of the undamaged orbit 'virtually' repaired the defect. A model of the repair was fabricated and used to cold-press a titanium sheet. Screw-holes, shaping, polishing and cleaning of the implant were done in our workshop. A notch in the implant vertically above the infraorbital nerve was added to help the surgeon position the implant.

Results Eight implants have so far been manufactured. Written feedback from surgeons (form) showed that the implants fitted the patient correctly, the screw-holes were in suitable number and place. Surgical intervention took about one hour; the functional and cosmetic requirements were fulfilled.

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Discussion After orbital trauma (accident, fight, assault) patients often suffer enophthalmus as a result of broken orbital wall and floor. The implants presented here acted as a new orbital wall or floor and avoid in-theatre harvesting and sculpting of other bone. Practical and cosmetic issues constrained the shape and size of the implant. The addition on the implant of an anatomical landmark proved to be a real asset for its rapid insertion. The routine service provided by the department is a demonstration of university-to-hospital transfer of technology. The implants were developed in conformance with the Medical Devices regulations for customised implants.

The Design of an Automatic Cooker Knob for People with Dementia.

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Introduction A cooker monitor system has been designed for the Gloucester Smart House project that will detect a dangerous situation and intervene to make it safe. It is designed to be appropriate for people with dementia.

This paper describes the development of an automatic cooker knob that can be retrofitted to most gas cookers.

Specification

1. The knob must reliably turn off a gas cooker ring in the event of a dangerous situation being detected.
2. It must be aesthetically pleasing and appropriate for a person with dementia.
3. It must fit most domestic gas cookers.
4. It must not interfere with the normal operation of the cooker.
5. It must be operable during mains power failure.

Design The knob is actuated by a constant tension spring. This is a compact energy storage device that can store energy and release it when required with very little power input. A ratchet mechanism enables the spring to be wound and cocked using human input on the first occasion the knob is used after activation, leaving the system ready for use.

The mechanism to release the spring once it had been cocked was explored using solenoids. These have the advantage of being able to be set up to release a catch on the loss of power. Solenoids were found to be too bulky, so an alternative was sought.

The use of shape memory alloys made possible the design of an automatic cooker knob that fits the front of most gas cookers and looks like many other cooker knobs. At the time of writing the knob is being prepared for evaluation in people's homes.

Tremor detection using Actigraph with Wavelet analysis

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Introduction Patients with Parkinson disease or other movement disorder show the arm movement in various patterns according to person or degree of disease. To classify the pattern of movements, basic swing motions of the arm were performed and analyzed. On the basis of this analysis, the tremor can be detected in the movement of the patients.

Methods

a) Data acquisition

An actigraph is attached to the wrist and recorded the acceleration of it. Six different motions were experimented. The acceleration of each motion was

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measured and transferred from actigraph to personal computer via RS232.

b)Wavelet Decomposition

The signal is decomposed to 4-level by the daubechies mother wavelet(db4) . It is decomposed to details and approximation.

c)Comparison parameters

For each experiment, the ratio between the wavelet coefficients power and the original signal power (RWO) is calculated. The ratio between X-axis wavelet coefficients power and Y-axis's (RXY) is calculated. 6 pattern movements are compared on the base of RWO and RXY.

Results In the case of tremor, RWO has the highest value in D2 at X, Y axis and the amplitude is so high. It means that the tremor is 2.5~5Hz movement. This is distinct property discriminated from others. By this simple property, being tremor or not can be determined.

Conclusion The movement condition of the patients as well as normal persons can be monitored by using actigraph. We prepared the analysis foundation and planned to construct the unconstraint movement monitoring system.

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Objective Visual Acuity Test System Using Video Eye Tracking

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Introduction Objective visual acuity test is useful method to measure visual acuity of infants and malingering patients [1]. We developed a objective visual acuity test system using computerised optokinetic nystagmus and video eye tracking system.

Methods For stimulation, we used suppression method. We induced an optokinetic nystagmus by moving stripes on monitor and then suppress nystagmus by present a non-moving stimulus inside moving stimulus. Video eye tracking system [2] determines existence of optokinetic nystagmus through image processing. By measuring minimum stimuli which suppress the nystagmus, we can estimate visual acuity. And then we analyzed a correlation between objective and subjective visual acuity.

Results We constructed a database through 152 eyes from normal volunteers. Subjective visual acuity was measured by C-chart. The correlation between objective and subjective visual acuity was 0.93.

Conclusion We developed a objective visual acuity measurement system. We can find a correlation between our system and subjective visual acuity, so it can be used to estimate visual acuities of infants and malingering patients. This system can classify a group of the low visual acuities but is not applicable to the high acuities because of resolution of stimulus. It

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should be modified by considering other methodology of stimulation.

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Design and Testing of a New Hip Protector for the Elderly

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Abstract Current hip protectors that are worn in garments have a low patient compliance and the only stick on design has many mechanical shortcomings to be effective as a pad for protection. A new protective pad that was attached to the subject's skin, was designed from anatomical data from patients who are at risk of a fracture of the hip from a fall onto the greater trochanter and tested mechanical for it's force shunting and energy absorption characteristics. Twenty eight samples of polyurethane foam and hard shells of ABS of the new design were subjected to impact tests for their force shunting and energy absorption characteristics to determine the optimal density of foam and to compare these characteristics with two common commercial devices, one of which is a stick on design.

The anatomy around the greater trochanter was determined by the use of a flexicurve former and the radii in two planes used to construct the base of an impact test rig. The test samples on this rig were

subjected to the energies and peak forces known to cause a fracture. The new design was comparable to the existing pads for the mechanical protection, appeared more comfortable to wear in all ranges of movement of the hip, and was attached to the subject away from the skin over the greater trochanter.

Investigations on the Cutting Performance of Different Biocompatible Abrasives in Abrasive Waterjets for the Use in Orthopaedic Surgery

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In the last four years the investigation on abrasive waterjets for the use in orthopaedic surgery was performed very intensively by research groups in Hannover and Hamburg. As abrasive materials in these tests water soluble and biocompatible abrasive have been used.

After a theoretical investigation regarding the biocompatible properties of some water soluble powders they were tested for their general applicability for the use in an abrasive waterjet process. For this first investigations the Abrasive Water Injection Jet (AWIJ) was selected because of the easy to handle adding of the dry abrasives. The test material was bone cement (PMMA).

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At a water pressure of $p=100$ MPa, a diameter of the water nozzle $d_w=0.3$ mm, a diameter of the focussing tube $d_f=0.8$ mm, a traverse rate $v=100$ mm/min and a standoff distance $s=1$ mm different abrasive materials were tested. For sugar, xylit and sorbit cutting results with depth of cut between 4 and 6.5 mm were obtained.

The abrasive waterjet has very good properties which will open new application fields for this technology in orthopaedic surgery. The research groups in Hannover and Hamburg will go on with their investigations with the target of implementing the abrasive waterjet as an established tool for orthopaedic surgeons.

Practical switch design as a response to client feedback information.

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Introduction Switch assessment is a common requirement for clients referred to the Technical Aids Service of the Regional Medical Physics Department, enabling them to access control of a wide variety of aids. Historically, these have included wheelchairs and communication aids, and most recently, computers [1]. Assessment protocols have been in use for many years, but are essentially functionally based. This paper examines the ways in which a client reacts psychologically to their switch, and how this can have a major impact on switch design.

Results A small selection of custom made switches will be presented, designed to aid a variety of physical handicaps. Brief technical details will be given, but the emphasis will be placed on how the design of the

switch was shaped by the clients own reactions to switching.

Discussion Discussion will centre upon the physiological, and psychological factors which had the most influence on the switch design.

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