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Practical experiences of interpreting time-average hologram fringe patterns from three-dimensional objects

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# Applications of The Queenwood Special Computer System

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In this paper a new Special Computer System will be described which has been designed on the basis of five years of research into the needs of patients who have suffered brain damage. It is suitable for children and adults born with mental or multiple handicap and also for victims of road traffic or other serious accident.

The System is being used to assist patients who may be as severely disabled as the profound mental handicap classification. Applications for the system extend from Speech Therapy to Occupational Therapy, Education and Leisure and include the following:

- Expansion of controlled movement
- Expansion of intellectual capacity
- Expansion of communication capability
- Determination of optimum working level
- Measurement of progress
- Potential for brain diagnostics and sensory assessment.

Systems are now in use in major mental handicap hospitals, adult training centres, psychology departments and special schools.

Following a brief review of the hardware of the Queenwood Special Computer System, the main emphasis of the paper will be directed to the concepts used for the development of capability and communication. It will be concluded with a discussion of the potential and practicalities for the use of the System to assess the severity and probable location of centres of brain damage.

## HARDWARE

Of primary importance are the practicalities of the System.

- 1) It requires no previous technical or computer skill from the supervisor.
- 2) It is very easy to use.
- 3) It is rugged and robust.

The main features of the System are as follows:

- i) It can accept an extremely wide range of input switches and control devices. No patient is too disabled to be able to use the System. A chart indicating the full potential of input switches is given in fig. 1.
- ii) It has very comprehensive reward facilities including coloured lights, sounds, speech, vibrators, control of battery toys such as dogs, robots, cars and trains plus control of mains devices such as disco lights, tape-players and furniture vibrators or

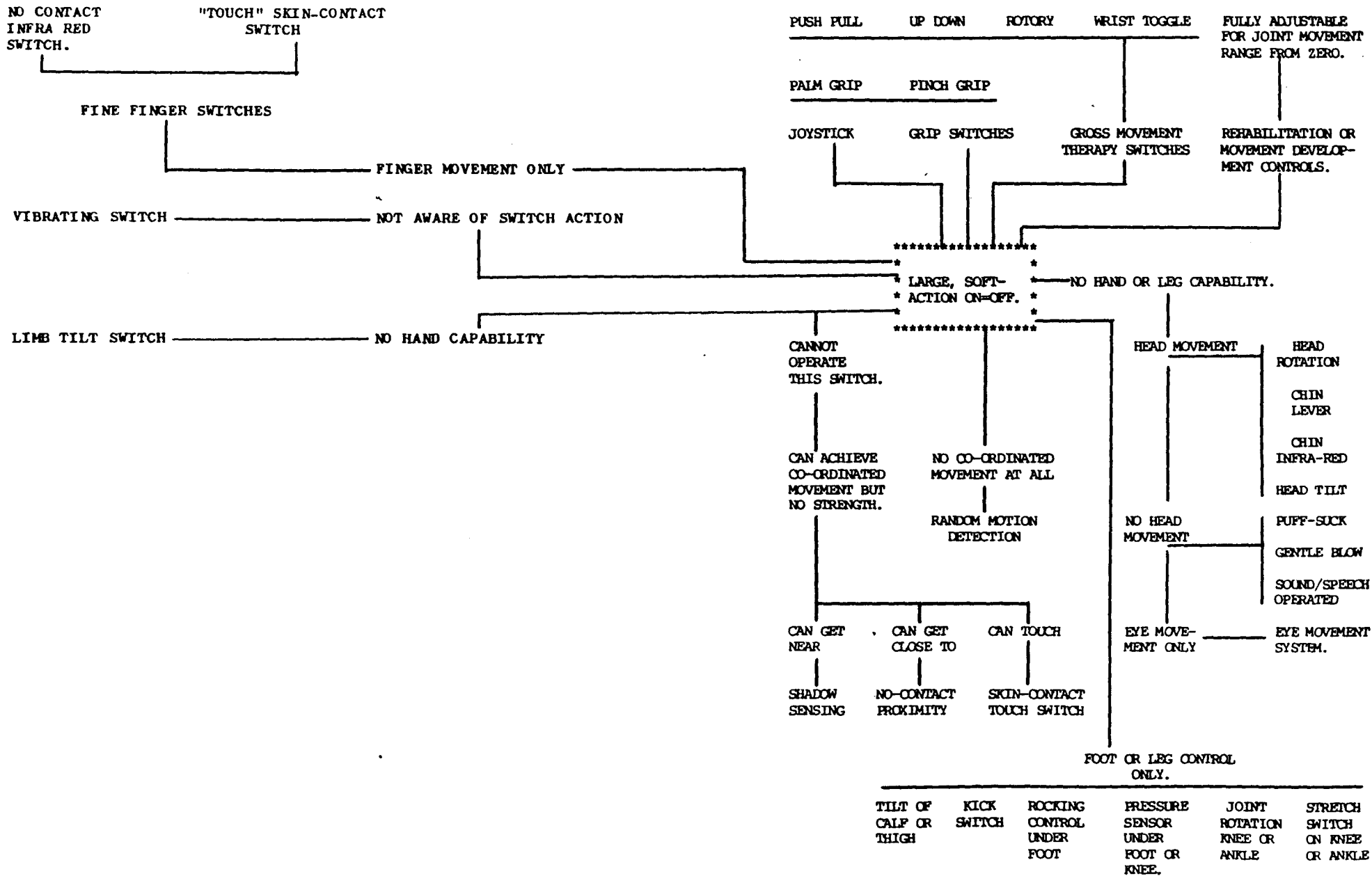


FIGURE 1.

walkways. No matter how impregnable a patient is in their disability, the System has the facilities to attract attention and to develop interest.

- iii) A flat display panel is normally used for most early work with the System and the facility to control a television or colour monitor will soon be available.
- iv) The System incorporates high quality artificial speech which is used for general comment, reward and guidance. The clarity of utterance is important to a mentally handicapped user.
- v) Almost every programme incorporates the facility to provide a quantitative analysis of the performance of the user. It is thus possible to prepare charts to indicate the changes in specific capability and to verify the actual extent of progress.

The starting point for applications for the Queenwood Special Computer is a child or adult who has never previously volunteered activity. This may be a young child with spina bifida or rubella syndrome or an adolescent or adult who has never been able, or has never wanted to try something. The importance of the user "wanting" to be involved, due to the effectiveness of the reward modalities and being able to be involved because of the wide range of possible input switches, is the essential feature which accounts for the success of this System. Thus even the random wafting of a limb or other uncoordinated activity, by a child or adult lying on a mattress can be detected and used to change the lighting colour around them, to produce music or to make the plinth on which they are lying vibrate. In time the association between their action and the response becomes appreciated. There are very few patients, even with very severe disability who do not make this connection. From this fundamental beginning it is possible to refine the interaction with the System so the user is helped to reach the maximum of their capability.

## THE DEVELOPMENT OF MOVEMENT AND MANIPULATIVE ABILITIES

People who are severely disabled may not have an obvious part of their anatomy, the movement of which is readily under their control. This may be because of spasm or it may be that the facility is very small and is just not apparent. In most cases however, there is some ability to exert control. It is also likely that the degree of control presently obvious is far below what they could achieve. By the judicious choice and progression of switches and control devices, it is possible to explore this facility and to expand it to its limits. It is appropriate therefore to indicate the natural progression from the unco-ordinated situation to the more refined use of specific task development devices. The sequence of progressive complexity of switch mechanisms is summarised in fig. 2.

Control of a switch begins with a simple on-off device which peculiarly suits the initial capabilities of the user. Once reliable control of this is achieved they should be introduced to a switch which demands a mite more of their ability. The progression then develops naturally from switches which require movement in a single direction only, to ones which require

movement in two dimensions and then to ones where movement in three dimensions is necessary. At each stage the user begins with a switch where there are physical guides on their movement in order that their opportunity for success is maximised. As these constraints are reduced so the demands on the user's control skill is increased. The importance of the light pen as a switch is thus very important and the accuracy with which a user can control it can indicate a great deal about the user's arm behaviour.

Once a switch is identified which is within the compass of a new user to operate reliably then it becomes of interest to increase the demands of the switch. If it is a straight press on-off switch then the switch could be made stiffer to operate, that is fit a spring inside it or a similar type of switch could be tried which is slightly smaller. The former change explores limb strength and stimulates muscle development and the latter change looks at the user's ability to co-ordinate the positioning of their limb when endeavouring to operate the switch. It could also be pertinent to investigate the results of locating the switch in a situation which requires a slightly larger arm movement to locate. Always the emphasis should be on small but steady increases in complexity and positioning. By so doing the ability of the user can be expanded. No matter how small an initial movement may be, the appropriate concentration upon it coupled with a powerful reward can often achieve significant improvement. By way of example a special switch was developed to respond to tiny elbow rotations. At the outset the user could only move the wrist by about one millimeter following a traffic accident. By making this tiny movement the switch enabled the boy to switch on the television or to control a train set. A sensitivity control on the electronic part of the switch made it possible to ask for a fractional increase in joint rotation and by so doing the range of movement could be built up.

## THE EXPANSION OF INTELLECTUAL CAPACITY

The concepts underlying programmes for the expansion of intellectual capacity need to be considered on three levels. These are:-

- 1) The acquisition of essential knowledge;
- 2) The development of ability to handle that knowledge;
- 3) The identification of limitations.

Whereas the first of these identifies directly with daily life and the material which a normal child is expected to absorb, the second leads to the realm of psychology and the third into neurology. A further factor of fundamental importance to the successful use of a computer system by a brain injured user is the absolute necessity for a continuous range of programmes. We have adopted the term, "Programme Raft" to express this aspect of the software concept. It means that a user can progress easily from their current programme to one of an adjacent level whether that be upwards in difficulty or laterally to approach the same or similar task from a different direction. A mentally handicapped user who, having discovered that they can do things, is naturally likely to enjoy working with the System and will tend to want to continue to use it. The effectiveness of the System in this connection is exemplified by reports of profoundly handicapped mature adults who are prepared to spend a quarter of an hour working with this System where previously they had refused to concentrate on any given task for more than a few seconds.

The question of what is "essential knowledge" can be answered by considering the information which is acquired by a normal child. (White) Such themes as learning the spoken names for pictures, the parts of the body, letters of the alphabet and colours all form part of the basic essential cognisance. This fund of knowledge is enhanced by abstract concepts such as "right and wrong", "up and down", "left and right" and the sensory gradations including "darker, lighter", "louder, softer" and so on.

In the same way that the stages of movement could be distinguished into a natural progression so also can the stages in the ability to handle knowledge. Starting from the very lowest level the requirement is for "awareness". The user is required to notice that something has happened. At a slightly higher level the stimulus they are to notice becomes more refined or detailed. It is not just a blatant happening but rather a more specific occurrence which may only be presented in one sensory modality. An example of this stage is the assessment of sensory ability. A user is asked to respond to various combinations of visual, auditory or tactile stimuli which may vary in intensity, in spatial position and intrinsic complexity. While the response sought from the user is exactly the same as at the awareness level, the stimuli are of lower level and can be developed to a considerable degree of sophistication.

Following the perceptual level the user's ability to distinguish between stimuli is investigated by a series of discriminatory tasks. At the early stages it is necessary for the user to react when they perceive the stimulus, then it is necessary for the test stimulus to be distinguished from a trial set of alternatives and then the various aspects of memory are brought into play using spatial and temporal snap routines. By this stage the question of recognition becomes important. It is necessary to be certain that a user actually knows a certain symbol and remembers it rather than that they can identify it during the test programme alone. Is their recognition as accurate if the test symbol is presented not fully drawn or if there is spurious detail in the display? Above this stage very exciting possibilities exist for exploring the user's abilities to deduce, to reason, to plan and to develop and modify strategies. At these stages it is important to expand the model from a linear axis of intellectual capability into an orthogonal set, one of which is the intellectual capability and the other memory. The ability to "learn" is a combination of these two.

Progressions are of the utmost importance. What has been described earlier has indicated a natural general progression of increasing intellectual complexity. Lateral progressions are equally important as also is the facility to approach a given task from a number of directions. Consider two examples.

- To develop the importance of attending to an area of illumination. This is obviously a prerequisite to the presentation of any visual information. With a single switch awareness or perception programme the user obtains the reward sequence to reinforce operation of the switch whenever the area is lit. Similarly the rewards can be activated when the illuminated area is "touched" with the light pen. Further if a joystick switch is used then rewards can follow the correct selection of the direction to move the switch into a lit part of the display screen.

- To consolidate the learning of a letter of the alphabet the user can discover the symbol is important by having it as a test shape in a snap routine and also approach it as a "snake" curve following task using the light pen.

## THE DEVELOPMENT OF COMMUNICATION ABILITIES

The ability to communicate is probably the most important factor which determines the degree of capability of an individual. Knowledge is verified by questioning and if communication is impossible it is likely that confusion of meaning will occur. It can be argued that the ability to interact with the environment prevents the practice of concentration skills and other learning processes and as a direct consequence mental development may suffer. People may become apparently mentally handicapped through limitation of physical movement and lack of communication ability.

The Queenwood Special Computer System has an extensive range of facilities for aiding the development of communication. These include:-

- 1) Matching of shapes and pictures.
- 2) Association of letters with pictures.
- 3) Matching of pictures with spoken names.
- 4) Learning to recognise letters of the alphabet or symbolics.
- 5) Learning Makaton signs.
- 6) Learning to draw letters of the alphabet using the light pen.
- 7) Further advances in free-hand control towards writing and drawing.
- 8) Learning to make vocal sounds.
- 9) Learning first words and to early reading.
- 10) Learning to construct programmes and sequences.
- 11) Learning to control things, learning cause and effect.

## THE POTENTIAL FOR DIAGNOSING THE LOCATION AND EXTENT OF BRAIN DAMAGE

Mental processes are complex functional systems and are not localised in narrow areas of the brain but take place through the participation of groups of concertedly working brain structures. Such structures are hierarchical and consist of at least three levels of activity. The function of the primary area is to respond to the information detected by the various sensory systems. The secondary area forms an associative function on this data and the tertiary level interacts with other regions of the brain and is involved with the decision making processes. One of the most exciting opportunities presented by the Queenwood Special Computer is its use to explore the extent and locations of brain damage. This is possible for a number of reasons. Because any patient can exert influence over the System anyone can engage in programmes which can be used to investigate brain behaviour. Even severely handicapped patients tend to respond to the strength of the reward facilities and so it becomes possible to study patients who were previously inaccessible. By constructing programmes using neurological and psychological relationships it becomes possible to begin to explore the functioning of the various levels of the brain. Specific loss of facility can now be associated with damage at certain

locations in the cortex and deeper brain levels. Accordingly the judicious use of visual and auditory stimuli can lead to indications that a certain capability is missing and that this would be expected to correspond to damage in a certain area of the brain. The value and importance of such indications are that special therapeutic programmes on the Special Computer and otherwise can then be used to try to expand those capabilities which are identified as defective.

## CONCLUSIONS

Through the format of a specially conceived computer system it has been shown that considerable help can be given to a great many children and adults who, by reason of mental handicap or head injury have presently a very poor lifestyle. Early achievements of the system have included first speech and increases in concentration time. New concepts of programme design have been introduced and the potential has been shown for advances in brain diagnosis.

## REFERENCE

B.L. WHITE, "The First Three Years of Life", W.H.Allen, 1978.



- Random movement
- Specific movement - control of a single switch  
to suit anatomical capability
- Multiple discrete - control over more than one  
switch
- Two-way joystick switch
- Proportional reciprocal device
- Four-way joystick switch
- Switch panels or arrays
- Light pen
- Spatial switch arrays
- Task development systems

Fig. 2. Progression of Complexity of Switch Mechanisms