Intelligent Decision Support System for Eye-Hand Coordination Assessment

Learning to write is an important occupation of children [5, 10]. Problems with handwriting or drawing skills (graphomotor skills) are frequently the reason children in public schools are referred to occupational therapy services [8], [9]. There are five identified components that contribute to the quality of handwriting: kinesthesia, motor planning, eye-hand coordination, visuomotor integration, and in-hand manipulation [7]. Children with genetic anomalies or neurological disorders can also have problems with eye-hand coordination such as children with Down syndrome, cerebral palsy, and learning disabilities. All these diagnoses require intervention for eye-hand coordination and often for grip strength because these components are necessary for successfully performing activities of daily living such as dressing, feeding, drawing, and writing.

Assessing the eye-hand coordination skills of children with disabilities and making decisions on the next, more complex test by using crisp, quantitative terms may not be an optimum approach. Fuzzy logic [13] allows the aggregation of measured data and expert knowledge that is expressed in qualitative terms in a common mathematical model. A fuzzy automaton [14] can help in developing an intelligent decision system by recommending the sequence and complexity of the next test to be given. This recommendation will be based upon the results of the previously performed test and expert knowledge. The decision mechanism can be fine tuned as more test results become available.

Our goal is to develop an automated assessment and training procedure for children with eye-hand coordination problem. An automated assessment system is expected to reduce the burden and the associated cost of having a trained professional present at any assessment, or training session. The intelligent decision support system will be based upon a fuzzy automaton. By using qualitative (fuzzified) data from the previous test the system will make a decision on the complexity of the next test to be performed. A set of assessment tests, commonly used by occupational therapists, were chosen to implement the various functions using force, inertia and viscosity effects. A test bed will be used for these tasks that consists of a six-degree-of-freedom force-reflecting haptic interface device called PHANToM along with the GHOST SDK Software, and the Intelligent Decision Support System software.

The research approach is based upon the comparison of the performance of an experimental and a control group. The experimental group is exposed to standard occupational therapy tests as well as tests performed on the haptic robot. The control group works only on the standard tests. The sequence of tests given to each group is shown in Table 1. The initial ($A_{Initial}$) and final (A_{Final}) data collection sessions will be used in the assessment of the baseline performance and the occupational performance changes of the subjects using the standardized assessments listed below:

	Experimental Group	Control Group
$A_{Initial}$	**Standardized Occupational Therapy Assessment Tasks (1 week)**	**Standardized Occupational Therapy Assessment Tasks (1 week)**
B	**Intervention using Haptic Device (8 weeks)**	**--**
A_{Final}	**Standardized Occupational Therapy Assessment Tasks (1 week)**	**Standardized Occupational Therapy Assessment Tasks (1 week)**

The functional block diagram of the Intelligent Decision Support System (IDSS) is given in Figure 1. In its full configuration the system will be used for children in the age groups of 5 to 8 years. In the present phase of the research only children of 5-year old are considered. The system is made up of two major sections. The Main Controller section includes a computer workstation (PC), the PHANToM robot and the user interface software. The other key section is a simulated fuzzy automaton that is configured to accommodate the testing of the 5-year old children group. The task-level flowchart of the Intelligent Decision Support System is depicted in Figure 2.

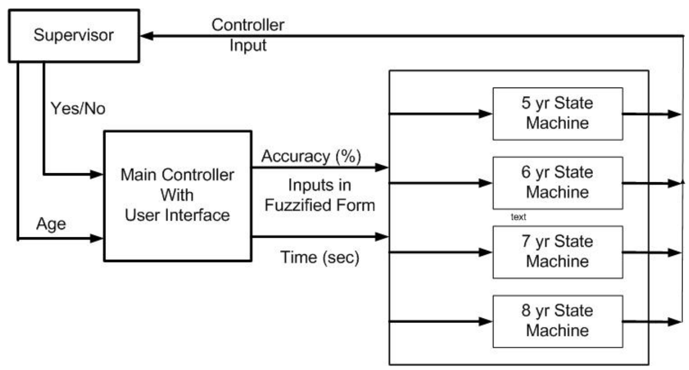

Fig. 1. Block Diagram of the IDSS

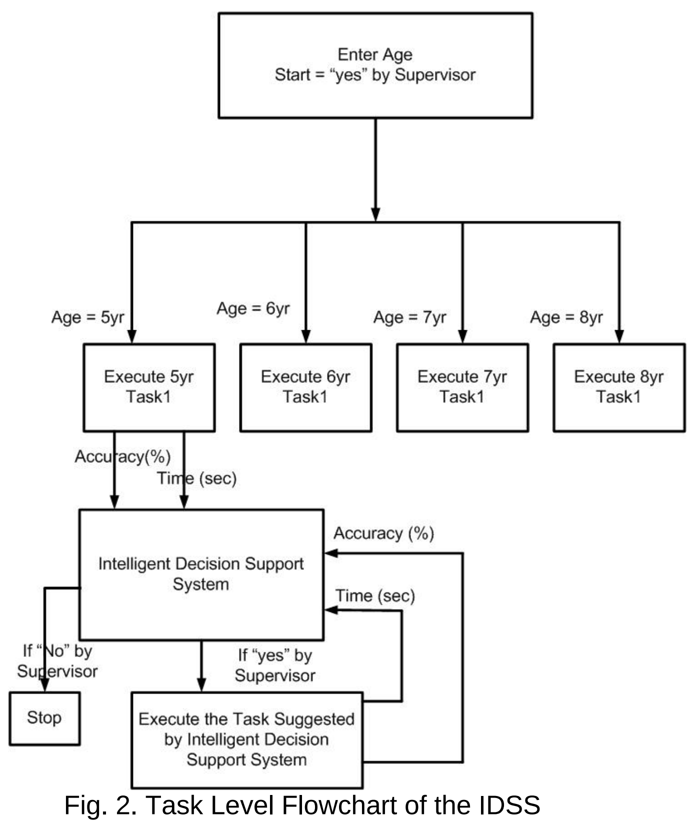

Fig. 2. Task Level Flowchart of the IDSS

The controller unit consists of the Graphical User Interface (GUI), which allows the therapist to enter the age of the subject and grants the permission to execute the tests suggested by the Intelligent Decision Support System. The main control unit takes the age and assigns the first task to be performed by the subject. It then calculates the accuracy (with respect to the number of times the subject is out of the desired path) and the time (in seconds) taken to carry on the task, then fuzzifies the values and provides them as inputs to the IDSS. The IDSS then makes use of the fuzzy automaton model to recommend the next test to be performed by the child. Based upon its present state and the fuzzified results of the test just performed the fuzzy automaton makes a transition to a new state. In this new state when it becomes the present state only one two-valued output is set, out of a 12-element output vector. This output is then used to choose the next task to be performed by the subject. Depending on his/her performance the subject may get stuck at some particular task level, or may move up to a more sophisticated level. If a subject performs really well the sequence of states will be as follows: 1, 4, 7, 11, and Stop. The level of difficulty in a task increases as the state number increases. However, the approval by the therapist is required to proceed with any new test. The therapist can also abort the test at any point in time. The state transition graph of the fuzzy automaton for the 5-year old children group is shown in Figure 3.

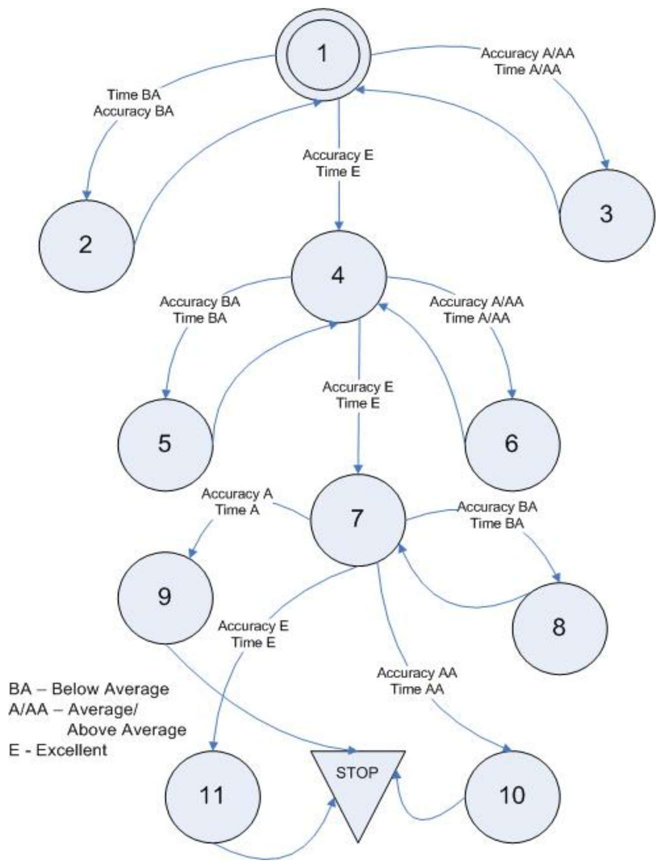

Fig. 3. State Transition Graph of the Fuzzy Automaton

The states are designated as follows: (1): initial state and no effects, or assistance, (2) and (3): design with maximum force assistance and minimum force assistance, respectively, (4): design with curves rather than with sharp edges in the path but no effects, or assistance, (5) and (6): design with minimum inertia effect, and medium inertia effect, respectively. The labyrinth for these states is illustrated in Figure 1. In State (7) the labyrinth in Figure 2 is considered with no effects, or assistance. State (8) is a design with force assistance. States (9-11) are designs with minimum, medium and maximum inertia effects, respectively. State Stop is the last possible state in the sequence of tests. The number of states visited depends upon the performance of the subject. This state transition graph has been developed by following the advice of an occupational therapy expert. The state transition conditions are subject to further experiments and refinements. The input membership functions used in evaluating the state transition conditions are given in Figures 4 and 5.

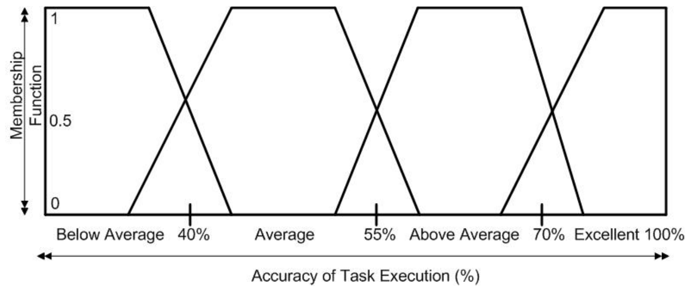

Fig. 8. Membership Functions for Accuracy

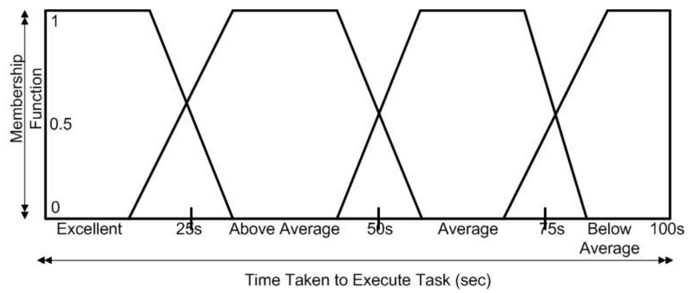

Fig. 9. Membership Functions for Time Taken