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(54) Title: COMPUTER ASSISTED LEARNING SYSTEM
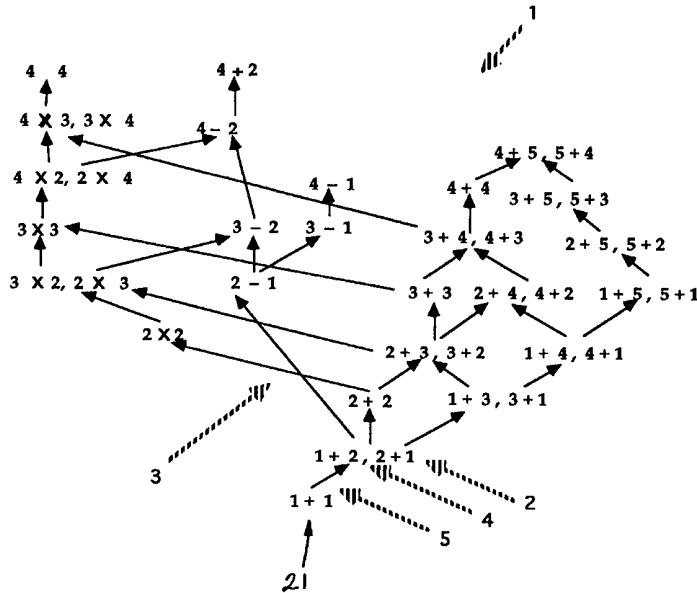
(57) Abstract

The system is loaded with a database of developmental networks and associated activity modules. The user selects a node in a developmental network and an associated activity module is activated which gives the student a multimedia presentation of some area of learning. The student's responses are evaluated and the corresponding node is marked as passed or failed accordingly. The nodes in a network are connected by links between nodes for a skill and nodes for easier skills that a student should have, it is expected, if the student has that skill. The student's choice of activity if restricted according to which nodes in a network have been failed. Interfaces for allowing the user to make a selection among the available nodes are also disclosed.

COMPUTER ASSISTED LEARNING SYSTEM

The present invention relates to computer assisted learning
systems in general whether the learner is an adult, a child
or otherwise, which may include the case where the learner is
5   a heuristic computer system.

Some computer assisted learning systems structure the
activities that a user may engage in according to their
difficulty, and the activities are presented to the user, the
learner, in that order. In some systems the user may have an
10 entirely free choice of which activity to attempt next.
Either way the user may suffer frustration or boredom because
he or she will choose activities at random, or be presented
activities, which are too easy or too hard and hence which
are of no benefit to the user.

15 It is an object of the invention to provide a system that to
some extent guides the user to appropriate activities.

Preferably some choice is left to the user which emphasises
and exercises responsibility and helps to maintain his or her
interest.

20 In a preferred embodiment the system allows the separation of
the user interface and the educational content, which
facilitates the development educational aspects of a system,
lets the user configure the interface to suit him or herself,
and allows the same material to be used across a wide range
25 of age and (dis)ability.

The invention makes use of what are termed herein as
developmental networks which encode information as to the
relative difficulty of the various skills that a user is to
attain. As will be described below the skills are not simply
30 arranged into a linear order.

According to the present invention there is provided a
computer assisted learning apparatus for operating upon a
database comprising at least one developmental network, the

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network having a plurality of nodes, each representing a
developmental skill or an inference concerning such a skill,
and links between nodes, each link being between a node for a
first skill and a node for a second easier skill, the
5   database further comprising interactive activity modules
associated with the nodes,
        the apparatus comprising
        means for allowing an interactive activity module
defined in the database to be selected,
10   means for presenting a selected activity module defined
in the database to the user whether visually, audibly or
otherwise,
        means for allowing the user to interact with an activity
so presented,
15   means for recording at least some of the user's actions
during or responses to the presented activity, and
        means for evaluating at least some of those recorded
actions or responses to decide, or provide an inference as
to, whether the user has attained a skill associated with a
20   node, and
        access prevention means operative in respect of at least
a particular node of a network at least for some of the time,
for preventing the user from accessing an activity module
associated with that particular node according to some
25   criterion based, at least in part, on the results of the said
evaluation for at least one activity module associated with
at least one other node of the said network.

Further the present invention also provides a computer
assisted learning program for operating upon a database
30   comprising at least one developmental network, the network
having a plurality of nodes, each representing a
developmental skill or an inference concerning such a skill,
and links between nodes, each link being between a node for a
first skill and a node for a second easier skill, the

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database further comprising interactive activity modules
associated with the nodes,

the program comprising

means for allowing an interactive activity module
5   defined in the database to be selected,

means for presenting a selected activity module defined
in the database to the user whether visually, audibly or
otherwise,

means for allowing the user to interact with an activity
10   so presented,

means for recording at least some of the user's actions
during or responses to the presented activity, and

means for evaluating at least some of those recorded
actions or responses to decide, or provide an inference as
15   to, whether the user has attained a skill associated with a
node, and

access prevention means operative in respect of at least
a particular node of a network at least for some of the time,
for preventing the user from accessing an activity module
20   associated with that particular node according to some
criterion based, at least in part, on the results of the said
evaluation for at least one activity module associated with
at least one node of the said network.

The said criterion may be based, at least in part, on the
25   results of the said evaluation for at least one activity
module associated with at least one node for an easier skill
connected to the particular node either by a single said link
or by more than one of said links, each of those links being
in the direction of a harder skill to an easier skill.

30   The means for presenting an activity module may be capable of
passing to an activity module arguments associated with a
particular one of a plurality of nodes associated with that
activity module, those arguments defining or adding to a

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definition of the skill represented by the node.

The apparatus may comprise means for presenting an activity module for one or more items in an electronic encyclopaedia.

5   The apparatus may comprise means for allowing a user to record an audio track of their own voice, for storing that track in association with a node and for allowing the user to replay that track.

The means for recording responses may include an on screen keyboard.

10   The means for evaluating the recorded responses or actions may comprise a means for marking the recorded responses and for providing corresponding marks.

The evaluating means may comprise means for reducing the marks provided by the means for marking to one or more
15   statistics.

The evaluating means and/or the access preventing means may produce or maintain at least one flag or value indicating whether the skill represented by a node has been attained by a user and/or whether the node is accessible to the user. The
20   said at least one flag or value may indicate, from time to time, the following conditions: that the user has not attempted an activity module associated with the node, that the user has attempted an activity module associated with the node but has not attained the skill that the node represents,
25   and that the user has attained the skill that the node represents. The said at least one flag or value may indicate, from time to time, the following condition: that the node is to be accessible to the user despite the user having attempted an activity module associated with the node but has
30   not attained the skill that the node represents. The said at least one flag or value may indicate, from time to time, the

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following condition: that the node is to be accessible to the user irrespective of whether the user has attempted an associated activity module or has attained the skill that the node represents.

5   The said access prevention means may be arranged to prevent access to nodes for which the user has attempted an associated activity module but has not attained the skill that the node represents. The said access prevention means may allow, after a period, access to a node for which an
10 associated activity module has been attempted but for which the skill that the node represents has not been attained. The said means for preventing access to nodes may allow access to a node for which the user has attempted an associated activity module but has not attained the skill that the node
15 represents once the user has subsequently attained the skill for an easier node that is connected to that node via a certain number of links, each in the direction of a node for a harder skill to one for an easier skill. That certain number of links may be one. Alternatively the said period may
20 be a predetermined period of time.

The said access prevention means may be arranged not to prevent access to a node merely for the reason that the user has attempted an activity module associated with that node but has not attained the skill that that node represents.

25 The said means for preventing access may always allow access to a root node, a root node being a node having no nodes for easier skills linked to it.

The means for preventing access may be arranged not to prevent access to a node elected by a user to be accessible.

30 The said criterion may be based on on which of the routes from a particular node to a root node has a node for which

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the user has attempted an easier skill but has not attained
that skill, the links making up said routes always being in
the direction of a harder skill to an easier skill.

The access prevention means may be arranged to prevent access
5   to an activity module associated with a node if on the only
such route or any one of such routes there is such a said
node.

The access prevention means may be arranged to prevent access
to an activity module associated with a node if on the only
10   such route or on all of such routes there is such a said
node.

The access prevention means may be arranged to prevent access
based on fuzzy or inferential logic criteria. That is to say
the evaluation of the user's actions during or responses to
15   an activity module may be more complex than simply saying the
user has passed or failed a node.

The apparatus may comprise a search engine for allowing a
user to enter one or more keywords and for returning a list
of activity modules that are associated with the keywords and
20   that are not prohibited to the user by the preventing means.

The apparatus may comprise means for presenting the activity
modules allowed to a user by the preventing means into a
hierarchical system of menus for presentation to the user. At
least some of the items on at least one of the said menus may
25   be presented graphically.

The apparatus may comprise means for displaying a graphic
having a layout corresponding to the interconnection of the
network and may allow the user to select among the activity
modules associated with that network that are allowed to the
30   user by the access prevention means. The means for displaying
a graphic may hide portions of the graphic representing nodes

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inaccessible to the user.

The apparatus may comprise means for presenting a list of
activity modules accessible to the user with the activity
modules for nodes in the same network as the or a node
5   associated with the last activity module attempted by the
user being presented first.

The apparatus may be arranged to allow the user to select
from among encyclopaedia entries allowed to the user by the
preventing means.

10   The system may, however, be arranged to choose activities for
the user from those accessible to the user. Preferably the
system is arranged to present the available activities in
turn cycling between them.

The apparatus may be operable with an activity module for
15   which the evaluation means operates to decide whether the
user has attained the skills of at least two different nodes.
Those two said nodes may be in the same or different
networks.

The apparatus may be arranged to allow navigation between
20   related networks, the representation of said networks
including links for that purpose.

The apparatus may be arranged to place restrictions on the
user's navigation between networks based on the results of
the said evaluation for nodes of those networks.

25   The apparatus may be arranged to guide the user, when moving
between one network and another linked to it, to a particular
node in said latter network, the identity of that node being
recorded in the representation of said networks.

The apparatus may be for operating on a network defined by a

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set of developmental criteria and whose representation
records those criteria or the degree of difficulty of
individual nodes of the network with respect to those
criteria, and the apparatus may comprise selection means for
5   selecting from the nodes in a network allowed to a user by
the access prevention means, one or more nodes having a
selected degree or degrees of difficulty with respect to the
developmental criteria. The said selected degree or degrees
of difficulty with respect to a particular developmental
10   criterion may be a certain degree of difficulty and all
possible greater degrees of difficulty with respect to that
developmental criterion. The said selection means may be
arranged to offer the user a choice among a group of nodes
selected by the selection means only once the size of that
15   group is below a certain size. If the said group of nodes is
above the said certain size the selection means may be
arranged to adjust, or allow the user to adjust, the degrees
of difficulty used to make the said selection of nodes.

According to the present invention there is also provided
20   apparatus for generating from a set of developmental criteria
a network for use with computer assisted learning apparatus.

An embodiment of the invention will now be described, by way
of example only, with reference to the accompanying drawings,
of which:

25   FIGURE 1   is an example of a developmental network used in
             the present invention.

     FIGURE 2   is a representation of a node of a developmental
             network and an associated activity module in an
             embodiment of the invention.

30   FIGURE 3   is an exemplary network illustrating the operation
             of the accessibility module of the present

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invention.

FIGURE 4   is an example of a graphic interface for allowing a
            user to select a node in a developmental network.

On using a system according to the present invention, loaded
5   with an appropriate database, the user of the system, a
     student, is allowed to choose for him or herself a learning
     activity to perform. That choice is, however, restricted by
     the system in a manner described below according to the
     student's past performance as measured by the system.

10   Figure 1 shows an example of what is termed herein as a
     developmental network 1. This example is for basic numeracy
     skills. Each node 2 of a developmental network represents a
     skill to be acquired by the student. In this example, each
     skill is simple addition, subtraction, multiplication or
15   division. The skills are linked by arrows 3 that represent
     what are termed herein as developmental implications. These
     developmental implications encode the expectation that if a
     student has attained a skill at the head end 4 of the arrow
     then he or she will already have attained the skill at the
20   tail end 5. The reason why the term implication is chosen is
     illustrated by the following. In a network comprising nodes
     A, B, C and D it is expected that if a student has attained
     either skill B or C then he or she will have attained the
     easier skill A. It is also expected in this example that if
25   her or she has attained skill D then he or he will have
     attained easier skill B and/or easier skill C. With those
     implications it is also expected that if he or she has
     attained skill D then he or she will also have attained skill
     A, but those implications do not lead to any expectation
30   between skills B and C. The directions of the arrows are the
     directions in which a student would be expected to progress
     and so are the reverse of the directions of the
     "implications" described above.

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The system of the present invention may work either with manually predefined networks or with networks that are generated automatically, either beforehand or as necessary during the operation of the system, from sets of what are
5   termed herein as developmental criteria as will be explained below.

Figure 2 represents node and activity modules, or objects (in the terminology of object oriented programming), within an embodiment of the system of the present invention.

10   Each node object represents a node 2 in a developmental network such as exemplified by Figure 1 and records a brief description 6 of the skill to be acquired and references 3 to related nodes, which references encode the information represented by the arrows 3 in Figure 1. Each node 2 also
15   records references 8 to one or more activity modules. Those may also include references 9 to activity modules representing entries in an encyclopaedia. The referenced encyclopaedia entries when activated in general present the user with some educational material relevant to the node's
20   skill more in the form of raw information than the other activity modules like a traditional encyclopaedia. The activity modules including encyclopaedia entries may have the user perform some task, the responses to which are monitored and are used by the apparatus of the invention to provide
25   feed back to limit the user's choice of which nodes and hence which activity modules and encyclopaedia entries he or she may visit. There need not be an individual activity module for each node. A module may be shared by several nodes each passing different arguments to it and for that purpose the
30   arguments may be stored in the node 2 associated with the encyclopaedia or activity module reference. In the example of Figure 1 a single activity module could be shared by all of the nodes for addition with the arguments stored being the

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integers to be added. A single activity module for the
encyclopaedia may be provided with the node storing the
headword for a particular entry and the activity module being
arranged to look up the material under that headword in an
5   encyclopaedia database. An activity module may not
necessarily subject the user to a monitored task but unless
that occurs visiting a module will not provide or add to the
said limitation on which activity modules he or she may
visit.

10   As mentioned above, the system guides a student to select a
particular learning activity and in use the system is
provided for that purpose with a database of activity objects
or modules. Once activated an activity object 7 gives
multimedia presentations 10 to the student. Each presentation
15   may include textual, graphical, video and audio information
to facilitate the student's acquiring a skill.

Each task for the student is characterised as having an input
and an output, the input being the information necessary to
solve the task and the output being the required response.
20   For example an activity module related to the easiest node of
the exemplary developmental network of Figure 1 may present
the input and output together in the expression "One and One
makes two". This presentation is either by on-line speech
synthesis or by an assembling a corresponding set of sound
25   files, sampled recording of natural speech. Whether much or
little information is presented to the user, the presentation
enters a test phase during which the user's responses 13 are
recorded. Once the user has gone beyong a given point, there
is no way of either exiting the system or trying anything
30   else without going through this test phase. In the test phase
only the input is given, either reworked as a question "What
does one and one make?" or as an incompleted sentence, "one
and one makes …".

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The system is preferably arranged to allow the user to decide
when the test phase is entered. Until that point the system
may be arranged to loop presenting a variety of activities
and games.

5   Reflecting what are obviously wide differences in educational
attainment, the balance between presentations with graphical
objects and with arbitrary symbols whether letters or
numerals, is one between networks. If a user fails to
complete a task or activity with numerals he or she may be
10   given the option of attempting the same task with objects.
The user who fails to add one and one presented as spoken
numerals can be given a related, but simpler, task involving
the same numbers of multimedia objects, such as apples and a
bag to count them into or spoken words subject to grouping
15   transformation and so on. By the same token if the user can
succeed at a given task carried out with objects he or she
may elect to attempt a similar task with written numerals.
This transition from a lower to a higher ranked network is at
the discretion of the user. But it is also subject to
20   evaluation by the system and determinable by the system
without the user's intervention. For the user unaware of the
issues involved not to mention the terminology, the
management of this transition by an abstract graphic is
appropriate.

25   Objects represented concretely are treated as being in a
different lower ranked network than they are when represented
by letters or numerals. Effectively this corresponds to the
difference between school and nursery. Nodes defined on
related sets of elements in separate networks are defined as
30   sharing a property. Preferably an audio track 11 is played as
described and the user is allowed to record his or her own

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track 12 with the instruction that he or she repeats the
predefined track. This user track may be replayed at will by
the user and may be saved for that purpose for a time when
the user revisits the node. This recording of the lesson in
5   the student's own voice is thought to be an effective aid to
learning.

An opportunity to perform practice tasks during which the
student's responses are not recorded may also be given and
the distinction between practice and test tasks may be hidden
10   from the student as appropriate.

Where the user is to make the responses, or indeed any other
form of input to the system, in textual form, the user may
use the standard keyboard or a special on-screen keyboard
with either suitably restricted or suitably enhanced
15   functionality may be provided. Suitable restrictions include
the elimination of all punctuation other than the full stop.
Suitable enhancements include the automatic capitalisation of
all letters not preceded by another character or preceded by
a full stop. The lower the user's sophistication and keyboard
20   skills, the more likely it is that the on-screen keyboard
will be preferred.

The recorded responses 13 are processed through several
stages of analysis. First a response marker 15 marks each
unit of the user's response. A unit of response may be a
25   single typed answer to a single question, for example "2" in
response to "What is 1 plus 1?" but it may be also a set of
answers or mouse clicks that the user must make to complete a
response. For example, {"2", "4", "6", "8"} are the responses
expected to the question "Which are the even numbers less
30   than 10?" The response marker 15 provides a mark for each
unit of response, which may be simply right or wrong but may
also be a grade. For example if the response to the last
example question above were {"2", "4", "8"} that would be

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almost correct. For younger users a response set may have
between 4 and 8 items; for older users sets may be larger. A
response set may be evaluated by scanning from left to right
or right to left or both and its mark may be determined by
5   inference rules.

To provide encouragement incorrect responses may cause the
activity module to present the user with another opportunity
to provide a correct response and that action of allowing a
repeat attempt may be factored into the mark provided by the
10   response marker 15. A unit of response may also be a set of
responses to a set of prompts where the expected responses
are correlated.

The set of marks 16 produced by the response marker 15 is
passed back to a mark analyser 17, preferably part of the
15   node module 2. This reduces the set of marks to a set of
statistics 18, for example, just a single percentage mark,
derived from the set of marks as a whole. Preferably the same
sort of statistic or statistics are generated for each node.

Clearly if the set of marks 16 consists of only a single mark
20   then no processing may be required. In this case it may still
be necessary, however, for the mark analyser to perform some
data translation. For example, the mark 16 may be simply a
flag indicating a correct or incorrect response when the
statistic 18 is a percentage mark. In such a case "correct"
25   may be converted to 100% and "incorrect" to 0%. The mark
analyser may be constructed to convert more than one sort of
mark, or set marks, into the same type of statistic or set of
statistics.

The last stage of response analysis is preferably to produce
30   a set of success and/or navigation flags 19 by a
success/navigation calculator 20. The function of the
success/navigation calculator is to control the user's access

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to nodes and hence the related activity modules which, of
course, includes related encyclopaedia entries. This it does
on the basis of the mark statistics 18 and navigation rules,
examples of which are described below. As an aid to this
5   process the success and navigation calculator may keep flags
indicating whether the skill associated with the node has
been obtained by the user, it may keep flags indicating
whether a node is to be accessible to the user, and it may
keep flags indicting both of those things.

10   The success/navigation calculator 20 decides, at a relevant
time as discussed below, whether or not the mark statistics
18, if indeed the student has yet attempted the node's
associated activity module, justify the conclusion that the
student has attained the node's skill. The criterion used is
15   one appropriate to the skill. For example, in safety critical
subjects and in learning a foreign language 100% correct
responses may be demanded whereas in school subjects perhaps
only 50% may be required (having subtracted a response rate
that would be expected from random responses). The system may
20   be arranged such that a common criterion may be used for all
nodes of a network and that criterion, or even each of
separate criteria for each node, may be set for a particular
student.

An example of the rules implemented by the success/navigation
25   calculator 20 and of the flags kept 19 is as follows.

A four state flag, or status variable, is kept being an
integer variable assigned one of four arbitrary values being
for example, 0, 1, 10 and 100. 1 is the default state of the
flag of a node before the user has been tested on that node's
30   skill (or before the user has been tested at some other node
which may affect the value of the flag, as is described
below). 0 indicates success, i.e. that the user has attained
the node's skill. 10 and 100 both indicate, in general,

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failure, i.e., where the node's skill has been tested but was
not attained. 100 is the normal value assigned for failure
but 10 is assigned where it is desired to allow access to the
user nevertheless. In this example 10 is assigned to failed
5   root nodes, root nodes being ones to which there are no
easier nodes connected, for example, node 21 in Figure 1.
Other nodes for which failure may result in a value of 10 may
also be specified by the designer of a network.

The success/navigation calculator calculates an accessibility
10   flag for a node as follows. The accessibility flag is set to
"accessible" unless an easier node connected to that node,
either directly or on any path to any root node, is set to 10
or 100 (i.e. > 1 in the scheme of values set out above),
which occurs in general if any of those nodes have been
15   failed. In those cases the flag is set to "barred". The
accessibility flag for a node is also always set to "barred"
if the success flag of that node itself is 100. The
accessibility flag is not set to "barred" for nodes having a
success flag value of 10 and that is irrespective of whether
20   easier nodes have been failed (which is of course irrelevant
for root nodes).

In this way the more difficult nodes beyond a failed node are
made inaccessible to a user making sure that he or she does
not attempt a task where failure is probable. For an ordinary
25   failed node, i.e. one set to 100, that node itself is
inaccessible and so the user is forced to try something
easier.

In order to allow the user to progress to a previously
failed node certain success/navigation flags having the value
30   100 are altered to 10 on the occasion of the user passing the
test of a particular easier node. Preferably that occurs for
the more difficult node or nodes directly connected to a just
passed node.

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Alternatively that may occur for those nodes within a certain
plural number of nodes beyond the just passed node. This is
suitable for networks having nodes of numerous finely graded
levels of difficulty and speeds the student's progress
5   through the network, but care should be taken to ensure that
a student is not led to nodes for which he is missing some
essential skill.

Always setting a failed root node to 10 ensures that at least
that node is always accessible.

10   An administration module may be provided having a function
allowing, for example, a user's teacher to set at his or her
discretion the success flag of a particular failed node to
the value of 10 to allow the user to attempt the failed
activity module again.

15   The 10 flag lets the system discriminate between nodes which
have been truly passed and those which have been made
accessible other than by the user's performance.

In an alternative embodiment nodes may simply be marked as
passed or failed and access to a node is denied if the node
20   itself, or an easier linked node, directly or via other
nodes, has been failed. To allow progress failed nodes are
marked as passed after a period of time has elapsed.

In another embodiment a failed node is not inaccessible
merely by reason of it having been failed itself but will be
25   inaccessible if an easier connected node has been failed.
This allows a student to repeat a failed node until he or she
attains the node's skill.

In another embodiment access is initially denied to all but a
root node or nodes. Access to further nodes is allowed only
30   once a linked easier node has been passed.

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In still another embodiment a longer history of the success
or failure may be built into the success/navigation flags
kept. For example, a value may be incremented each time a
node is passed and is decremented each time it is failed, the
5   node becoming inaccessible if that value falls below a
certain level. An accessible node is, for example, made
accessible by automatically incrementing the value,
preferably by a smaller amount, from time to time.

Preferably in both the preferred and other embodiments
10 described above a node is inaccessible, and is marked
appropriately for that, even if on only one of several paths
back to a root node, or nodes, there is a node that is marked
as failed. Figure 3 is an exemplary network with nodes 41 to
45 marked with the values of their success /navigation flags
15 for the scheme described above in which the flags have the
value 0, 1, 10 or 100; they are also marked with a cross if
they are inaccessible to the user. In this example the user
has passed the root node 41 but has failed node 42 one of the
two nodes 42 and 43 immediately connected to the root node
20 failed node 41. Nodes 44 and 45 are inaccessible even though
there are paths from those nodes to the root nodes 41 via
node 43.

In an alternative embodiment, if there are plural routes to a
root node, or indeed to root nodes if there is more than one,
25 from a particular node then that node is only inaccessible if
all routes to a root node are blocked by a failed node (i.e.
having a success/navigation flag of 10 or 100 in the scheme
described above).

The system may be used with more than one developmental
30 network, each represented by node objects. For example, in
addition to the simple arithmetic network of Figure 1 the
system may include a set of networks for literacy including
networks for reading, spelling and handwriting. In general

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these networks will have associated with them their own
activities. The system allows, however, for activities that
test skills in two different networks. For example, an
activity may present and test material relating both to the
5   operation of adding two to a number and the ability to spell
the word "two". Such joint presentations add to the interest
of the student. The system may be set either to record the
student response statistics generated in relevant nodes of
the relevant networks or to record only the statistics
10   relating to the network in which the student thinks he is
working because, for example, he reached the activity by
choosing to do something about arithmetic. The manner of
selecting an activity is explained below). The setting may be
one related to the student set by him or her or his or her
15   teacher or may be one specific to the activity.

The system may allow for an activity to test at the same time
more than skill in the same network.

The system is flexible in that it may be provided with a
database of networks and activities for any area of learning,
20   and new networks and associated activities may be added at a
later date.

In each of the embodiments described the accessibility rules
are applied by an accessibility module of the system which
traverses the networks loaded into the system examining the
25   success/accessibility flags to determine which nodes are
accessible to the student. This module makes the list of
accessible nodes available to one of several interfaces
described below. The system of the present invention may be
configured to include any combination of these interfaces and
30   the interface used by a student may be at his or her choice
unless specified by his or her teacher in the administration
module.

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Examples of suitable interfaces are described below.

A first interface is a module providing a series of
hierarchical menus. As has been mentioned above the system
may be loaded with a number of networks and associated
5   activity modules. Each of these networks also contains
information about how these networks may sensibly be
classified. For example, the subject of mathematics may be
divided into arithmetic, geometry, calculus, vector analysis
and so on. Each of these subjects may be divided into topics.
10   For example, geometry may be divided into two-dimensional
geometry, three dimensional geometry, projection geometry,
topology and so on. These topics may be further divided until
the area of study is of a size suitable to be represented by
a developmental network, which size will depend on the
15   subject matter, the age and developmental level of the
intended student and also on the network designer's
discretion. For example, a network for a higher developmental
level than the basic arithmetic of Figure 1 may include
negative and fractional numbers. The information about the
20   grouping is gathered by this interface module and is
organised into the series of menus. On the first menu are the
broad subjects such as mathematics, English, history.
Selecting one of these items leads the student to the next
level and so on until the entry for one network is selected.

25   The system may then display a list of only the accessible
nodes. Clicking on an item on the list for a node causes a
list of its related activity modules (including encyclopaedia
entries) to be displayed. Clicking on an item of that list
causes its related activity module to be activated. If the
30   node has only a single activity module associated it is
activated automatically without a list of activity modules
being displayed. The menus also include links to items in an
electronic encyclopaedia referenced by the accessible nodes.

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On the higher level menus no item is displayed unless it leads to an accessible node.

Alternatively the system may be arranged to select for the user an activity module from among those available to the student. This reduces the number of choice to be made and so is less boring. This is the preferred arrangement for the primary school level and for the teaching of a languauge.

A second interface module is a search engine which allows the student to enter keywords which are searched for against key words supplied for the purpose at each node. The search engine returns to the student links for only those nodes that have those key words and that are accessible as determined by the accessibility module. On selecting one of those links the appropriate activity module is activated. For an encyclopaedia entry key words include at least the headword for the entry. Activity modules may be categorised by other criteria and the search engine may be arranged to allow the user to search accordingly.

In one example, keyword are divided into two classes. One corresponds to keywords of bibliography and everyday life, the body, school, history, and so on. The other is a set of about thirty categories, all commonly encoded in grammar. Examples include animacy, volition, humanity, social status, reference to time, reference to spatial relations between the speaker, the addressee and a given object. Like any other keywords they can be taken as largely independent Boolean filters. They can be represented abstractly by appropriate multimedia devices such as positions in a grid, defined by colour displayed on a palette. They can be added to each other and the standard keywords. The difference isthat one set is narrowly finite while the other is not. The availability of a narrowly finite set of keywords eachThis provides a small set of keywords and faster searching than by

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bibliographic keywords alone.

For any given item in the lexicon, a link may be provided to
any other item. This link may have any one or more of a small
set of Boolean characters. These include the property of
5   conditionality, the fact that the arm is part of the body,
the hand is part of the arm, and so on, the property of
categorical relationship, the fact that a chimpanzee is a
sort of ape, which is a sort of primate, and so on. The
property of antimony, relating black and white, and any of
10   the recognised lexical properties of relationship including
etymological or productive derivation. A link between words
may exist without any of these conditions being satisfied.

Activity modules may be characterised by other criteria and
the search engine may be arranged to allow the user to search
15   accordingly. Entries may be categorised by sytactic category,
noun, verb and so on, by spelling, by sound, taking account
of either or both the beginning and the end of the word, by
length in terms of numbers of syllables, by morphological
regularity, or by frequency of use.

20   The system is usually used for the purpose teaching a
student. The keyword interface is also useful for the
allowing the student to find the answer to a specific
question that he or she may have. In such a use the access
preventing means of the invention will still operate to limit
25   the information available to the student to that for which he
or she has the relevant skills.

A third interface is a more directive suggestion module. If a
activated by the student then a list of accessible modules is
presented to the student. This list is, however, sorted in
30   the following order:

1. Nodes close by in the network to the last attempted node.

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2. The remaining nodes in that network.

3. Nodes of related networks, those being more closely
   related according to the subject hierarchy mentioned above
   being listed first.

5   A fourth interface module is provides a graphical means of
     selecting a network. Other means such as the fifth and sixth
     interface modules described later may be used for selecting a
     node within the selected network. Using the fourth interface
     module a network may be selected in one of two ways. A
10   display is provided representing a transparent lift on the
     outside of a building. By pressing up or down lift buttons
     the lift moves to a new window on the building, each window
     containing an illustration or text identifying a particular
     network, for example a network for spelling. The user
15   activates that network simply by clicking on it with the
     mouse. The lift may also be operated by pressing buttons
     marked with the names of general subject groupings of
     networks. If one of those buttons is pressed the lift moves
     and the doors open onto a corridor having doors bearing a
20   graphic or text identifying an individual network, which
     again the student may activate by clicking. For example if in
     the lift the student clicks the literacy button he or she may
     be taken to a corridor having doors for spelling, handwriting
     and reading. If the subject heirachy needs to be deeper a
25   door may be arranged to lead to a further corridor having
     doors for individual networks or possibly smaller groupings
     of networks. This interface is of general applicability in
     that it may be loaded with windows and doors for nay
     combination of networks loaded into the system. This is of
30   advantage to the user as it provides a consistent easy to use
     interface. This is in contrast to arranging for individual
     multimedia graphics for each group of subjects.

     In a preferred embodiment the success/navigation flags 19

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(see Figure 2) are calculated immediately on completion of an
activity module and advantageously are stored permanently so
that the student may at a later date return to the system in
the same condition as he or she left it at the end of a
5   session. The student's responses 13, the marks 16 or the mark
statistics 18 or some combination of those may, however, be
permanently recorded, either instead of or in addition to,
the success/navigation flags 19. (The stored data may be
reviewed by the student's teacher at a later date.) Recording
10   of student's responses 13, the marks 16 or the mark
statistics 18 also allows the success/navigation flags 19 to
be recalculated by the success/navigation calculator 20 if
the level of success required is changed by the student's
teacher as is allowed by the administration module. The
15   teacher would make such an adjustment in the light of the
experience of his or her students progress through a network.
Conceivably operation of the response marker 15 or the mark
analyser 17 could be changed after a student had used the
system and if that is to be permitted, the system is
20   preferably configured to store the student responses 13 or
the marks 16 in order to allow recalculation of the
success/navigation flags 19 once the system has been updated.

As foreshadowed above, a developmental network may be
generated automatically. The details of how this may be done
25   will differ with the subject matter of a network but in
general the process is, in a preferred embodiment, in two
stages. First a list of the individual skills for which the
network is to have nodes is generated and then those skills
are sorted or ranked into a network according to some rules
30   about the relative difficulty of the skills. Such a set of
rules is termed herein as the "developmental criteria" for a
network.

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A network is comprised of nodes. A node may be defined by the
point at which two criteria interact. Fort example, in
relation to primary arithmetic, if one criterion consists in
the size of the inputs and another consists in the nature of
5   the operation, the operation 1+1 instantiates the lowest
logically possible interaction between these criteria. These
and other criteria are defined below.

As has been described above nodes have the property that
dominate one or more other nodes, or are dominated by other
10   nodes, or both dominate and are dominated by other nodes, i.e
they are ordered into easier and more difficult nodes. Each
node may be assigned a unique identifier. A given node n is
defined by its relations of dominance to other nodes within a
given network. Indirect relations of dominance are computed
15   by progressively searching for these relations. For the set
of nodes dominated by n, let us say N', one step of this
searching is for the set of nodes dominated by the members of
N', and so on.

A network reflects "developmental implications"; to the
20   effect that if the user can do X, the user can do Y. In an
absolute and non-arbitrary way these relations are between to
or more skills in an academic subject area, such as
mathematics, literacy or a foreign language. These relations
are commonly reflected in the spelling of words different
25   levels of different orthographic or phonological complexity,
or, in the case of arithmetic between the steps of a table.
Performance in relation to a given task can be taken as
evidence in relation to one or more of these implicational
relations.

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Figure 1 shows the effect of a small part of a network
relating to the four arithmetical operations subject to
certain restrictions, as discussed below. The implications in
Figure 1 are all consistent. Each operation between two
5   inputs represents a node, at which the user can achieve
success at a particular level of development. A node
indicated by an arrow head implies or dominates the node at
the tail of the arrow. The length of the arrows and relative
height within the network are irrelevant. There is no
10   restriction on branchedness or the crossing of arrows. The
only relation is by the head to tail arrangement of arrows.

Figure 1 shows the lowermost nodes of a network defined by
the interaction of implicational, or developmental, criteria
15   concerning the operation and the size of the operands. The
restrictions are: A) that the output is a positive integer
(excluding computations where the output is a fraction or
negative); and B) that the output is distinct from the larger
of the inputs. This Network is designed to reflect both the
20   extent to which division is harder than addition and the idea
that 1 + 1 is the simplest operation and that 2 x 2 is the
simplest multiplication.

A more general set of criteria is defined below generally
25   what is taught in Britain today as primary arithmetic.

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1)   Given two cases of the same operation involving an
integer i and one other input, and an output j, the ranking
of the two operations is directly and positively related to
the value of or j, whichever is the greater; the higher this
5   value, the higher the ranking and the harder the calculation.

2)   Addition ranks lower than subtraction and
multiplication. Division ranks higher than subtraction and
multiplication. (Nothing is specified about the relative
10   ranking of subtraction and multiplication in relation to each
other.) The case where either of the inputs or the output is
not a positive integer ranks higher than the case where this
condition does not hold and higher than the case of a given
corresponding operation of division or subtraction.
15   (Fractions and negative numbers are harder than whole numbers
and positive numbers respectively. And at least one degree of
skill in relation to the appropriate non-commutative
operation is implied by any ability to manipulate a fraction
or negative number.) An operation where the output is a
20   negative number or reciprocal (one divided by an integer) is
ranked in direct proportion to the difference between the
output and the integer, one.

3)   The case where the output is distinct from the larger of
25   the inputs (alternatively, where a multiplicand or divisor is
not 1) ranks lower than the case where this condition does
not hold; operations which are trivial in their effects are
more difficult than those which are not.

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4)   The involvement of place-holding in the operation ranks
higher than the case where it is not involved, where the
effect is proportional to the number of place-holders
5   involved; the operation in 9 - 3 is easier than the operation
in 9 + 3. A computation where 10 is either the ouput or one
of the inputs is more difficult than a computation where the
10 is replaced by 9.

10   5)   Given two instances of multiplication or division
operation both involving a common value c, differing in that
one involves a base with the factors i and j, while the other
involves the prime k, such that k is greater than i or j, the
latter operation implies the former; the 7 times table is
15   more difficult than either the 8 times table or the 9 times
table.

6)   The involvement of zero as an input implies at least one
operation involving integers alone.

20

The above criteria favour simple, non-trivial operations with
positive, integral outputs of the smallest size, where the
representation does not involve place-holding. On the most
25   highly favoured value of all the criteria above, only one
operation is possible, namely 1+1. The inference module of

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the system applies in respect of all the user's test
responses in relation to a given set of networks. Test
responses can be grouped into sets of any size. In respect of
a foreign language these may consist in a single word. Where
5   a test response has more than a single element or keystroke,
the evaluation proceeds by scanning it in both directions. It
is thus determinable as correct or incorrect in any of a
number of ways which can be ranked and analysed by
appropriate rules. Errors can be categorised and flagged
10   according to whether they are likely to involve a
misunderstanding of the spelling, the grammar, and so on. In
a preferred embodiment for younger users the sets are likely
to be be between 4 and 8 in size. For older users this may be
one, as in the case of some aspects of foreign language
15   learning, or it may be a larger number such as 100. For any
size of set, the evaluation has a statistical element, as
mentioned above.

In default the system knows nothing about the user.
Accordingly the system may be arranged to cycle through a set
20   of conditions under which one or more of the criteria may be
reversed in favour of some selection other than the easiest.
In relation to arithmetic, by one such reversal the size of
the operands may be disregarded within given limits. If this
is three digits the system may then offer the user a sample
25   of additions involving three digit numbers, necessarily also
reversing the criterion involving placeholding. By another
such reversal, the criterion regarding place holding may be
reversed so as to offer the user a set of activities
differing marginally in whether place holding is involved.
30   For any response or set of responses, by one possible

extrapolation, it is assumed that if the user responds correctly to a task defined on a given basis he or she can respond correctly any such task. Taking the case where the user is given two randomly selected numbers to add, if the

5   user does so correctly the system infers that the user can add any two numbers. The system then generates a random sequence of such tasks. If the user performs to a given predetermined standard, getting the answer right in such and such a proportion or number of cases, the system

10   automatically resets another default, offering multiplications or subtractions with numbers within the same range. The time to complete a preliminary automatic assessment of an unknown user can be lessened by adopting the principle that the less the system knows about the user the

15   smaller should be the amount of positive evidence necessary before a criterion is reset from a default or easier case. At any point where the user starts to fail (at least to a degree such that performance is treated as falling below a given standard) each case of failure (and each element in cases

20   where the response is internally complex) is evaluated by all relevant criteria, namely those which refer to the task in any way. Let us suppose that the user fails to give a correct answer to the question: 'What is 97 divided by 13?' Without taking account of the nature of the error, i.e. in the

25   simplest case, the error may be due to the operation itself, the size of the elements, to the place-holding, to the fact that the correct answer is not a single positive integer or any combination of these. By the simplest implementation single explanations of an error are considered in turn.

30   Accordingly, by the task generation module a series of activities may be generated such that these hypotheses can be

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tested automatically by the system one at a time. By the
first such system test one of the numbers and one other is
submitted to another operation. By the second an operation of
division is offered with a similar pair of numbers where the
5   output is a positive integer, and so on. In five or so steps,
the system can accomplish this part of the assessment. By
applying the same principle on-goingly, by generating tasks
randomly within a given set of limits which may be adjusted
up or down by the user's performance , the user's current
10   working area can be rapidly adjusted to an appropriate area
within one or more networks. This is equivalent to a position
in a traditionally implemented paper-based course. But it
takes account of the user in a much more detailed and
accurate way.

15   On some values on some criteria, two operations involving the
same operator and the same inputs may be ranked one way on
one criterion and a different way on another. By 1), the
operation in 9 - 3 is more difficult than 8 ÷ 2. By 4), this
relation is reversed. The user, attempting to carry out the
20   operation in 8 + 2, is not privy to the mind of the system
designer. By the same token the mere fact that the user makes
an error does not mean that the task was impossible; the fact
of the error is just evidence pointing in a certain
direction. A failure with respect to such an operation may be
25   conditioned by either the value factors in 1) or the
representational factor in 4). Accordingly this invention is
preferably equipped with a series of inference rules which
carry out an on-line analysis on whatever data is available.
This provides an approximate estimate of an actual level of
30   intellectual function.

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The ranking of two arithmetic operations is commonly, but not
always, exclusive. According to the way criteria interact
there may be two inverse rankings of two operations differing
by only one factor, for example 9 + 3 and 9-3. Intuitively

5   this corresponds to human variation. In the same way, for
some individuals the reversibility of mathematical operations
is obvious. The subtraction in 2 - 1 is simply the inversion
of 2 + 1 under the condition that the inputs are treated as
non-commutative. For others this is less obvious. The

10   reversibility is expressed by the arrow from 2 + 1 to 2 - 1
in Figure 1.

Some logically possible interactions generate inconsistencies
in more complex cases where the output is not a positive
integer. On these criteria the fractions in 1/3, 2/3, 27/64,

15   are ranked in this order of difficulty. But the role of the
prime 7 in the numerator or the denominator, in in 1/7, 1/14,
7/8, 7/16, 7/144, may contribute differently to the ranking
for different individuals. The differences between 'zig-zag'
and more vertically upwards paths through a network like that

20   in Figure 1, express the possibility of variation across
individuals in what they find difficult.

It should be noted that a failure with respect to a test item
does not denote that the item in question is impossible for
the user. Such a failure is just evidence of the fact that it

25   may be.

The separation between networks each defined as a logically
possible interaction between criteria permits a large number
of different, but logically well-defined developmental paths.
For different users different concepts may be more difficult

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and so from time to time different users will find it easier
to progress through one of the networks than the other. This
allows a user to find his or her path through the concepts of
a particular area of learning in an efficient manner.

5

Educationally it may seem pedantic to ask whether learners
should, for example, start rehearsing subtraction with single
digits only when they can add pairs of digits within a
certain range, or when they can add single digits with a
10   particular degree of confidence and accuracy, and so on. But
previously where educational materials were presented in
strict linearity - as in a book - a decision on such points
is forced. Allowing multiple networks for the same area of
learning allows the possibility that there may be some
15   variation between individuals on such points.

The intention here is not to suggest that the sets of
developmental criteria for basic arithmetic set out above are
definitive. The definition of networks in terms of formal
criteria, rather than simply defining them node by node, is
20   intended to allow and indeed encourage the progressive
development of the invention as an educational tool. In the
light of experimentation, any given implicational criterion
can be amended.   It may for instance, be appropriate to amend
or redefine the criterion 6) above, an explicit hypothesis,
25   in the light of experience. Further criteria may also be
provided for related subject matter of grater or lesser
difficulty. For example, criteria may be provided for
numeracy defining exponents or logarithms.

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Networks of different difficulty may nevertheless share developmental criteria. For example, an easier network than that of Figure 1, is for performing arithmetic as a concrete operation, e.g. by moving groups of objects about the

5   display. In such a network multiplication may still be considered more difficult than addition for example.

Networks of different difficulty may have recorded in their representations links to each other. The interface by which a student chooses his or her next activity module may use that

10   information to allow the user to move to a harder and easier networks than the one he or she is presently using. These links may organise the networks themselves into a network, and restrictions may be placed on the student's movement between networks, for example, by using similar rules to

15   those outlined for restricting access within a network as described above. For that an appropriate criterion of success may be that a certain proportion of all the nodes have been passed, or at least not failed, or that the a proportion or all of the leaf nodes (those to which no more difficult node

20   is linked) have been passed or not failed. Further the representation of a network may also record suitable nodes at which the user could start depending whether he or she has come from a harder or an easier network. Preferably the user is directed to a root node when moving to a harder network

25   and to a node some distance above a root node when moving to an easier network,

If information is available in the system as to the developmental criteria used to define a network, a fifth interface module to be described below may be used with the

30   system, and indeed it is the preferred interface for reasons that will become apparent. The information may be available either because it is recorded in the representation of each

node how the developmental criteria come into effect for that
node, which may be arranged irrespective of whether the
network was generated automatically or was designed manually.
It is also possible for the module for generating a network
5   automatically, if indeed that is being used, to be arranged
to generate the information as needed.

The fifth and preferred interface module deals primarily with
the current settings of any defaults as entertained by the
apparatus in relation to a particular network. The network
10   itself my be selected by any appropriate means described
above. In default, the system cycles within an area defined
by a set of nodes, i.e. it automatically presents the user
with activity modules in turn without the user having to
choose his or herself. This area may be less than one defined
15   by the set of nodes from which the user has not been
debarred. Essentially this corresponds to the notion of work
of a given degree of difficulty where the difficulty
fluctuates within a finite range. Given such a set of nodes N
around which the system is currently cycling, there is a set
20   of more difficult nodes N' immediately dominating one or more
members of N, such that access is not debarred by virtue of
the evidence of the user's performance. In the preferred
embodiment the interface directs the user to a member of N'
selected randomly or otherwise.

25   In this interface the user fires a small red ball which
arches in a long trajectory towards a larger striped ball 35
of the sort illustrated in Figure 4 on which a black ball 33
the same size as the red ball is attached in the middle of
one panel exactly on the equator. The red ball knocks the
30   black ball off position, attaching itself in the same
position. The

striped ball is spinning and within a small number of
rotations, each lasting less than a second, the red ball has
itself become black and the process can be repeated. The
position and size of the target, and the size and colour of

5   the artillery might be varied randomly. Such variation would
greatly enhance the interface. The black ball represents a
member of N'. In response to the activity of firing the ball
the system redirects the user to an activity module for one
of the nodes of N' and redefines the sets n and N'

10   accordingly. Under the condition defined above, where there
is no such member for a particular user at a particular time,
for instance where only one or more root nodes are available
to the user the ball graphic may be unavailable. In the case
of the user reaching the point where there are no higher

15   ranked nodes other than any to which access may be prohibited
by virtue of recorded failures, the apparatus may respond by
not providing another red ball.

The ball graphic is a single instruction by the user to the
system to make his or her tasks harder in one single respect

20   on one criterion. This may be to progress from one step of
place holding to two, or from the set of positive integers to
include either fractions or negative numbers, and so on.
Movement in the opposite direction is brought about by the
access preventing means when the user fails a node.

25   The ball graphic is, of course just exemplary and the
promotion of the user to more difficult tasks may be in
response to some other user input or indeed may be performed
by the system, for example, on the evidence or user
performance or at intervals of time.

In the preferred embodiment for all levels of use the user
does not by default control which of the accessible nodes is
being selected by the ball graphic. It is possible for the
user to control the attachment of the ball to the target (in
5   particular the stripe to which it attaches) and to know the
academic significance of this. This effect can be achieved by
displaying (at the user's option) the academic significance
of a particular stripe when the mouse cursor is over that
stripe Using an appropriate tool the larger ball can be
10   rotated one stripe at a time. It is preferred for ease of use
for the system to cycle within a small set of available
nodes, one of which is randomly selected to be represented by
the black ball.

To give the user, particularly the very young child, some
15   control over transition between concrete and symbolic
representation, a second tool applies to the graphic of the
two balls. By this tool the larger ball can be raised or
enlarged in some highly visible way. In some contexts,
particular in primary school, this allows the user to
20   determine to some degree whether his or her work should be
in respect of multimedia objects or written words or numbers.
This raising and enlargement may be reversible.

Essentially the interface is designed to maximise interest,
surprise, and personal involvement, with a minimum of
25   repetition and administration. In the current version of the
system there is from one activity to another approximately
four mouse clicks, each a natural response to the perceived
difficulty of a task.

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Without any intervention by the user the promotional effect
of this module is carried out automatically on the basis of
an inference to the effect that the user is ready for tasks
of a more difficult sort. For this purpose, two constants may
5   be assigned to a body of work, the number of items in a
continuous series of trials and the proportion correct. As
soon as this criterion is reached, one randomly selected
default is automatically reset, equivalent to a firing of the
red ball.

10

Through the action of the success/navigation calculator the
user may find that his or her choice becomes restricted to
the root node or even such that no nodes are available.

A directive suggestion module is automatically activated at
15   this point guiding the user appropriately to the next node.
The direction given is more subtle than for the directive
suggestion module described above as the third interface.
Nodes from networks defined on at least one of the same
developmental criteria as the present network are located and
20   preferably the user is guided to nodes having a similar or
easier degree of difficulty on the shared criteria.
Preferably the user is first guided to nodes in a linked
easier network and then to nodes in other networks in the
subject area.

25   In an embodiment for a subject area where the user's target
is narrowly defined within small limits a sixth interface
module displays the network as a graphic. That graphic may be
of the moon. In contrast to the fifth interface module
described above it does not make use of developmental
30   criteria and so may be used in the absence of information

about those. Once a particular network is selected the
graphic appears directly representing the network and its
nodes in a single display. When the graphic is complete there
is for each node a region of the moon having a flashing spot
5   within it. The links between nodes (i.e. those that have
arrows in the representation of Figure 1) are represented by
the areas for those nodes being contiguous. The root node (in
the case that there is exactly one) is represented by the
lowermost edge of the moon. Regions for more difficult nodes
10   branch off with the same structure as the network. Only
accessible nodes are visible, however, and it is the
student's goal to complete the graphic by attaining the
skills for all the nodes. Initially this interface may only
show the area for the root node. More difficult but
15   accessible nodes may be added by the user by clicking a
control on the screen. A hint of an inaccessible node may be
given by having the area for that node appear briefly as the
mouse pointer passes over it. Clicking on an accessible node
leads to the activation of the corresponding activity module.
20   If the set of accessible nodes is restricted because the user
has failed a node then the graphic is reduced accordingly.

A further aspect of activity module selection, as follows,
may be included in the system. A set of activity modules may
be developed along some theme, for example, a highly
25   graphical set, or a set using a traditional text based
approach. If activity modules of two or more such types are
provided for the same network then the user may be allowed to
choose among them each time he or she selects a node.
Alternatively the user may choose using a general
30   administration module which sort of activity he or she would
like to use, with that choice being applied automatically on
each subsequent node selection.

Another function of the administration module may be to allow

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the user to specify what level of confirmation or feedback he
requires for the inputs he or she makes with the keyboard or
mouse.

The present invention may be implemented on a general purpose
5   computer such as a personal computer (PC).

The same basic system may be used in may areas of education
from the primary school to industrial training; the system
simply has to be loaded with developmental networks and
associated activity modules for the subject to be taught.

10   The basic system may also include library routines for use by
the node and activity modules. For the activity modules it
may provide multimedia presentation routines, audio playback
and recording facilities and routines for recording the
student responses in a central store. For the node modules it
15   may provide library routines for storing the response
statistics and success/navigation flags in a central store
and also for calculating the success/navigation flags from
the response statistics.

The system may also be implemented as an independent unit and
20   that may be in the form of what is known generally as a
console. Such a unit may accept cartridges holding at least
one developmental network and associated activity modules.
Such a unit may also accept cartridges for recording a
particular students progress so that he or she may carry that
25   information form one console to another.

The user of the computer assisted learning system may not be
a person but an artificial learning heuristic system, for
example a suitably programmed computer. The interface between
such a system and the system of the present invention may be
30   electronic for abstract skills, may be mechanical if the
artificial system is for performing some mechanical task, and

may be aural or visual if the artificial system is for
performing some aural or visual task. While an artificial
system may not suffer the problems of frustration, boredom or
disappointment that the system of the present invention seeks

5   to avoid or relieve, the use of the present system may result
in the more efficient programming of an artificial learning
system since time is not wasted on skills that the artificial
system has no hope of performing at a particular point of its
training. If an artificial system is to be so trained then it

10   is necessary for selection among the permitted activities to
be performed by a module, which may be provided as part of
the present invention or as part of the artificial system, or
by a human operator. The strategy for selecting the next of
the permitted activities to performed may be a random one. It

15   may be instructive to compare the efficiency with which a
particular artificial system becomes educated with different
strategies

The system allows different users to be more or less thorough
in the way they exploit the flexibility of the network. Slow

20   learning users will need to exploit that system more
thoroughly than relatively fast-learning users. The system is
flexible in the sense of system development. It can be
provided with a database of networks and activities for any
area of learning. New networks and associated activities may

25   be added at a later date.

In an embodiment for individual use by adults the
administration module may be configured to be relatively more
accessible to the user than in an embodiment for a primary
school classroom. In such an embodiment facilities may be

30   provided for the creation by the user of additional networks.
This in effect allows the user to become the network
designer.

The system seeks to learn what the user is capable of

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learning in relation to a particular subject area and to
constantly revise its own estimate. While this estimate is
always approximate, it achieves an increasingly close
approximation over time.

5   In all implementations a distinction may be drawn between
research activities determined by the user and didactic
activities determined by the system, as provided by the
system designer. This distinction is more evident in an
implementation intended for an adult or A-level student,
10   particularly where the system is applied to the learning of a
foreign language. Whatever the balance between teaching and a
research facility in the design of a particular
implementation, the user is formally evaluated with respect
to the materials provided. This evaluation entails reference
15   to the principle of the network. Where the system is used to
teach the user rather than as a facility for his or her
research, activities may be either generated on-line or
called up from a hard-coded data-base. These activities may
be initially presented with the answer, i.e. as a rote memory
20   task, or with no answer, i.e. as problems.

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CLAIMS:

1. A computer assisted learning apparatus for operating upon
a database comprising at least one developmental network, the
network having a plurality of nodes, each representing a
developmental skill or an inference concerning such a skill,
and links between nodes, each link being between a node for a
first skill and a node for a second easier skill, the
database further comprising interactive activity modules
associated with the nodes,
        the apparatus comprising
        means for allowing an interactive activity module
defined in the database to be selected,
        means for presenting a selected activity module defined
in the database to the user whether visually, audibly or
otherwise,
        means for allowing the user to interact with an activity
so presented,
        means for recording at least some of the user's actions
during or responses to the presented activity, and
        means for evaluating at least some of those recorded
actions or responses to decide, or provide an inference as
to, whether the user has attained a skill associated with a
node, and
        access prevention means operative in respect of at least
a particular node of a network at least for some of the time,
for preventing the user from accessing an activity module
associated with that particular node according to some
criterion based, at least in part, on the results of the said
evaluation for at least one activity module associated with
at least one node of the said network.

2. Apparatus as claimed in claim 1 wherein said criterion is
based, at least in part, on the results of the said
evaluation for at least one activity module associated with

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at least one node for an easier skill connected to the particular node either by a single said link or by more than one of said links, each of those links being in the direction of a harder skill to an easier skill.

3. Apparatus according to claim 1 or claim 2 wherein the means for presenting an activity module is capable of passing to an activity module arguments associated with a particular one of a plurality of nodes associated with that activity module, those arguments defining or adding to a definition of the skill represented by the node.

4. Apparatus as claimed in any preceding claim comprising means for presenting an activity module for one or more items in an electronic encyclopaedia.

5. Apparatus as claimed in any preceding claim comprising means for allowing a user to record an audio track of their own voice, for storing that track in association with a node and for allowing the user to replay that track.

6. Apparatus as claimed in any preceding claim wherein the means for recording responses includes an on screen keyboard.

7. Apparatus as claimed in any preceding claim wherein the means for evaluating the recorded responses or actions comprises a means for marking the recorded responses and for providing corresponding marks.

8. Apparatus as claimed in claim 7 wherein the evaluating means comprises means for reducing the marks provided by the means for marking to one or more statistics.

9. Apparatus as claimed in any preceding claims wherein the evaluating means and/or the access preventing means produce or maintain at least one flag or value indicating whether the skill represented by a node has been attained by a user

and/or whether the node is accessible to the user.

10. Apparatus as claimed in claim 9 wherein said at least one
flag or value indicates, from time to time, the following
conditions: that the user has not attempted an activity
module associated with the node, that the user has attempted
an activity module associated with the node but has not
attained the skill that the node represents, and that the
user has attained the skill that the node represents.

11. Apparatus as claimed in claim 9 or claim 10 wherein said
at least one flag or value indicates, from time to time, the
following condition: that the node is to be accessible to the
user despite the user having attempted an activity module
associated with the node but has not attained the skill that
the node represents.

12. Apparatus as claimed in claim 9 or claim 10 wherein said
at least one flag or value indicates, from time to time, the
following condition: that the node is to be accessible to the
user irrespective of whether the user has attempted an
associated activity module or has attained the skill that the
node represents.

13. Apparatus as claimed in any preceding claim wherein the
said access prevention means is arranged to prevent access to
nodes for which the user has attempted an associated activity
module but has not attained the skill that the node
represents.

14. Apparatus as claimed in claim 13 wherein the said access
prevention means allows, after a period, access to a node for
which an associated activity module has been attempted but
for which the skill that the node represents has not been
attained.

15. Apparatus as claimed in claim 14 wherein the said means

for preventing access to nodes allows access to a node for
which the user has attempted an associated activity module
but has not attained the skill that the node represents once
the user has subsequently attained the skill for an easier
node that is connected to that node via a certain number of
links, each in the direction of a node for a harder skill to
one for an easier skill.

16. Apparatus as claimed in claim 15, wherein the certain
number of links is one.

17. Apparatus as claimed in claim 14, wherein said period is
a predetermined period of time.

18. Apparatus as claimed in any one of claims 1 to 12 wherein
said access prevention means is arranged not to prevent
access to a node merely for the reason that the user has
attempted an activity module associated with that node but
has not attained the skill that that node represents.

19. Apparatus as claimed in any preceding claim wherein the
said means for preventing access always allows access to a
root node.

20. Apparatus as claimed in any preceding claim wherein the
means for preventing access does not prevent access to a node
elected by a user to be accessible.

21. Apparatus as claimed in any preceding claim wherein said
criterion is based on on which of the routes from a
particular node to a root node has a node for which the user
has attempted an easier skill but has not attained that
skill, the links making up said routes always being in the
direction of a harder skill to an easier skill.

22. Apparatus as claimed in claim 21 wherein the access
prevention means is arranged to prevent access to an activity

module associated with a node if on the only such route or
any one of such routes there is such a said node.

23. Apparatus as claimed in claim 21 wherein the access
prevention means is arranged to prevent access to an activity
module associated with a node if on the only such route or on
all of such routes there is such a said node.

24. Apparatus as claimed in any preceding claim comprising a
search engine for allowing a user to enter one or more
keywords and for returning a list of activity modules that
are associated with the keywords and that are not prohibited
to the user by the preventing means.

25. Apparatus as claimed in any preceding claim comprising
means for presenting the activity modules allowed to a user
by the preventing means into a hierarchical system of menus
for presentation to the user.

26. Apparatus as claimed in claim 25 wherein at least some of
the items on at least one of the said menus is presented
graphically.

27. Apparatus as claimed in any preceding claim comprising
means for displaying a graphic having a layout corresponding
to the interconnection of the network and allowing the user
to select among the activity modules associated with that
network that are allowed to the user by the access prevention
means.

28. Apparatus as claimed in claim 27 wherein the means for
displaying a graphic hides portions of the graphic
representing nodes inaccessible to the user.

29. Apparatus as claimed in any preceding claim comprising
means for presenting a list of activity modules accessible to
the user with the activity modules for nodes in the same

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network as the or a node associated with the last activity
module attempted by the user being presented first.

30. Apparatus as claimed in any preceding claim allowing the
user to select from among encyclopaedia entries allowed to
the user by the preventing means.

31. Apparatus as claimed in any preceding claim operable with
an activity module for which the evaluation means operates to
decide whether the user has attained the skills of at least
two different nodes.

32. Apparatus as claimed in claim 31 wherein the two said
nodes are in the same network.

33. Apparatus as claimed in claim 31 wherein the two said
nodes are in different networks.

34. Apparatus as claimed in any preceding claim arranged to
allow navigation between related networks, the representation
of said networks including links for that purpose.

35. Apparatus as claimed in claim 34 arranged to place
restrictions on the user's navigation between networks based
on the results of the said evaluation for nodes of those
networks.

36. Apparatus as claimed in claim 34 or claim 35 arranged to
guide the user, when moving between one network and another
linked to it, to a particular node in said latter network,
the identity of that node being recorded in the
representation of said networks.

37. Apparatus as claimed in any preceding claim for operating
on a network defined by a set of developmental criteria and
whose representation records those criteria or the degree of
difficulty of individual nodes of the network with respect to

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those criteria, the apparatus comprising selection means for
selecting from the nodes in a network allowed to a user by
the access prevention means one or more nodes having a
selected degree or degrees of difficulty with respect to the
developmental criteria.

38. Apparatus as claimed in claim 37 wherein said selected
degree or degrees of difficulty with respect to a particular
developmental criterion is a certain degree of difficulty and
all possible greater degrees of difficulty with respect to
that developmental criterion.

39. Apparatus as claimed in claim 37 or claim 38 wherein said
selection means is arranged to offer the user a choice among
group of nodes selected by the selection means only once the
size of that group is below a certain size.

40. Apparatus as claimed in claim 39 wherein if the said
group of nodes is above the said certain size the selection
means is arranged to adjust, or allow the user to adjust, the
degrees of difficulty used to make the said selection of
nodes.

41. Apparatus for generating from a set of developmental
criteria a network for use with apparatus according to any
one of the preceding claims.

42. A computer assisted learning program for operating upon a
database comprising at least one developmental network, the
network having a plurality of nodes, each representing a
developmental skill or an inference concerning such a skill,
and links between nodes, each link being between a node for a
first skill and a node for a second easier skill, the
database further comprising interactive activity modules
associated with the nodes,
        the program comprising

means for allowing an interactive activity module
defined in the database to be selected,

means for presenting a selected activity module defined
in the database to the user whether visually, audibly or
otherwise,

means for allowing the user to interact with an activity
so presented,

means for recording at least some of the user's actions
during or responses to the presented activity, and

means for evaluating at least some of those recorded
actions or responses to decide, or provide an inference as
to, whether the user has attained a skill associated with a
node, and

access prevention means operative in respect of at least
a particular node of a network at least for some of the time,
for preventing the user from accessing an activity module
associated with that particular node according to some
criterion based, at least in part, on the results of the said
evaluation for at least one activity module associated with
at least one node of the said network.

43. A computer assisted learning apparatus for operating upon
a database comprising at least one developmental network, the
network having a plurality of nodes each representing a
developmental skill and links between nodes, each link being
between a node for a first skill and a node for a second
easier skill, the database further comprising interactive
activity modules associated with the nodes, substantially as
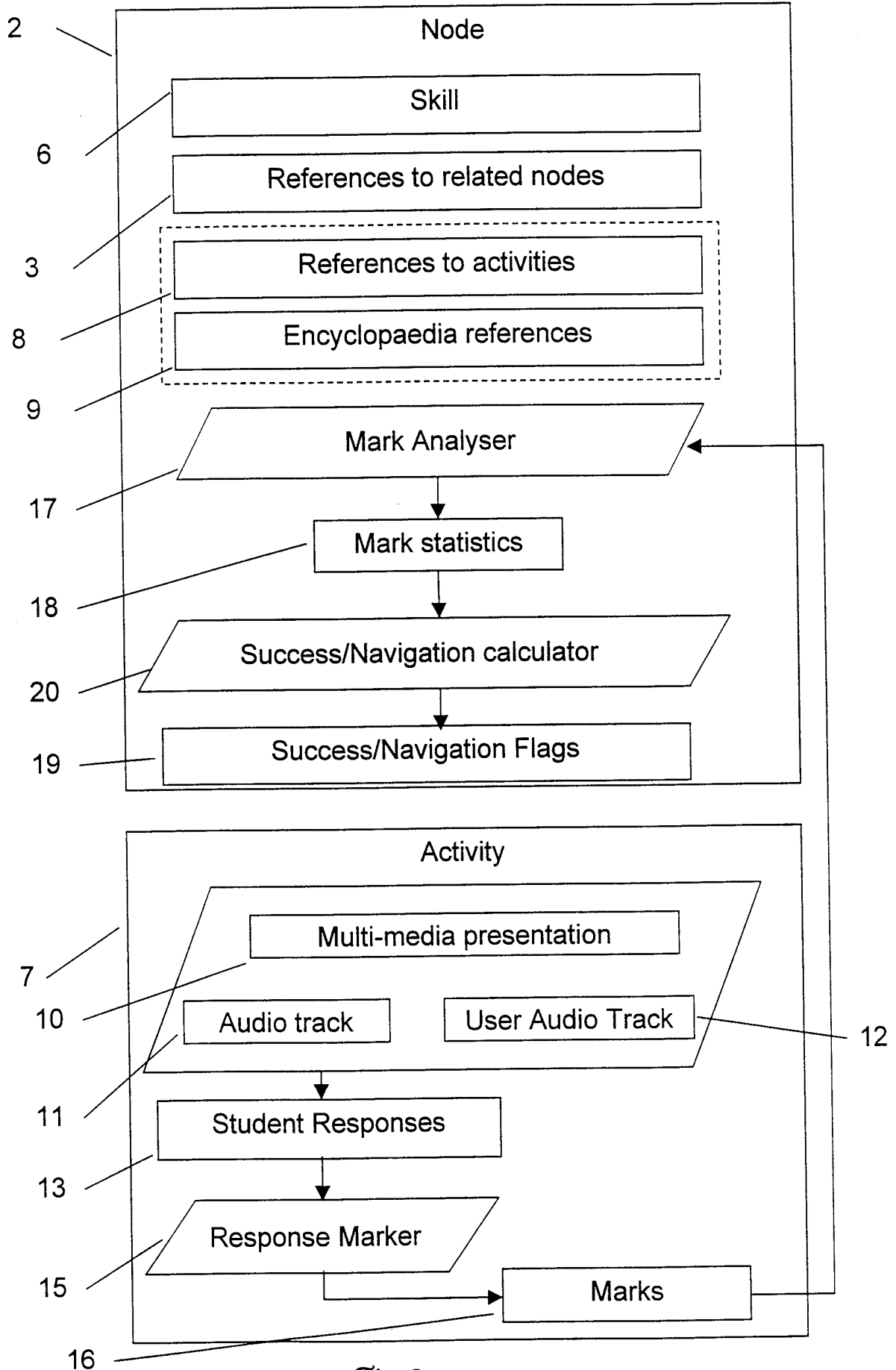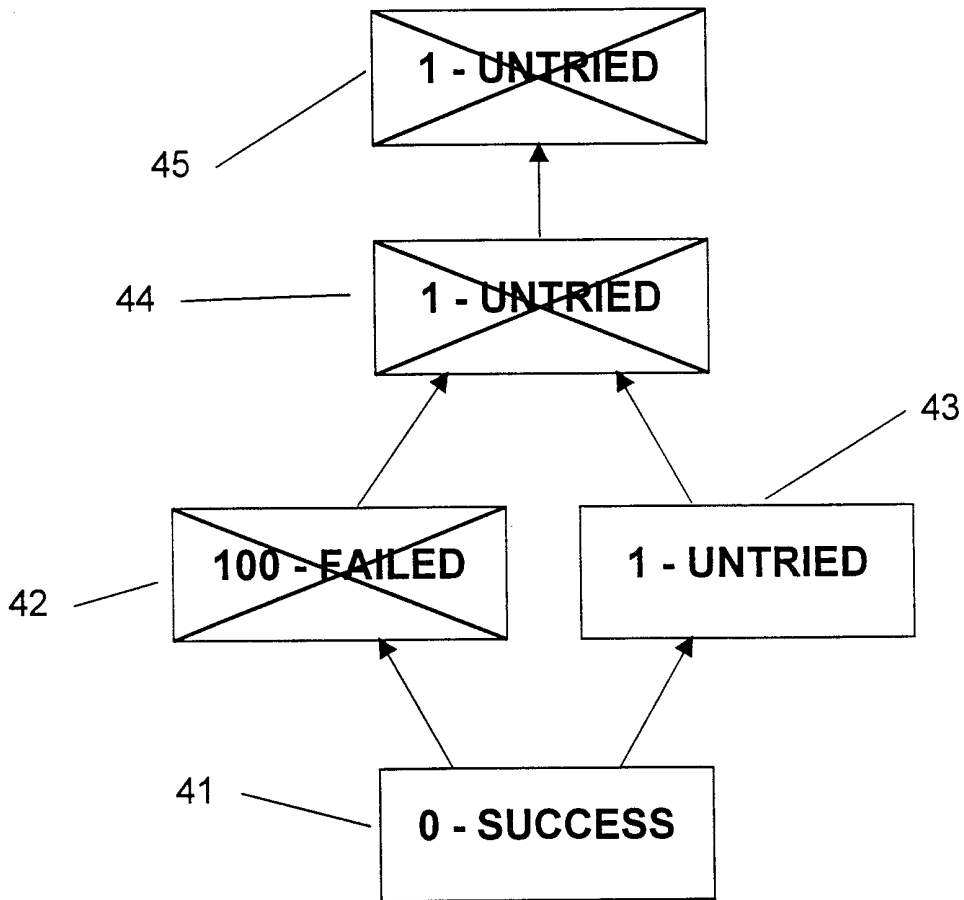herein described.

1 of 4
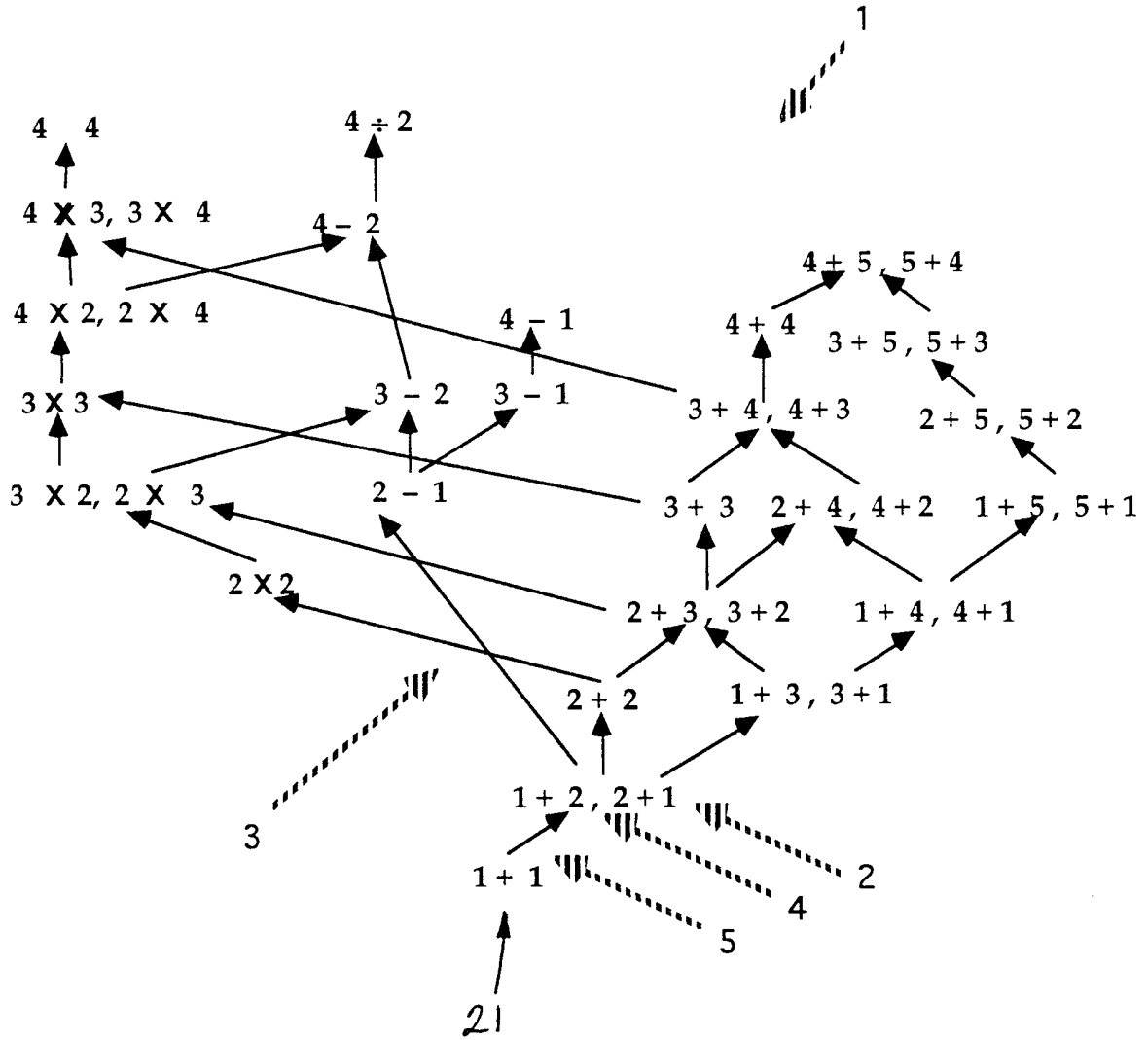
Fig. 1

Fig.2

Fig. 3

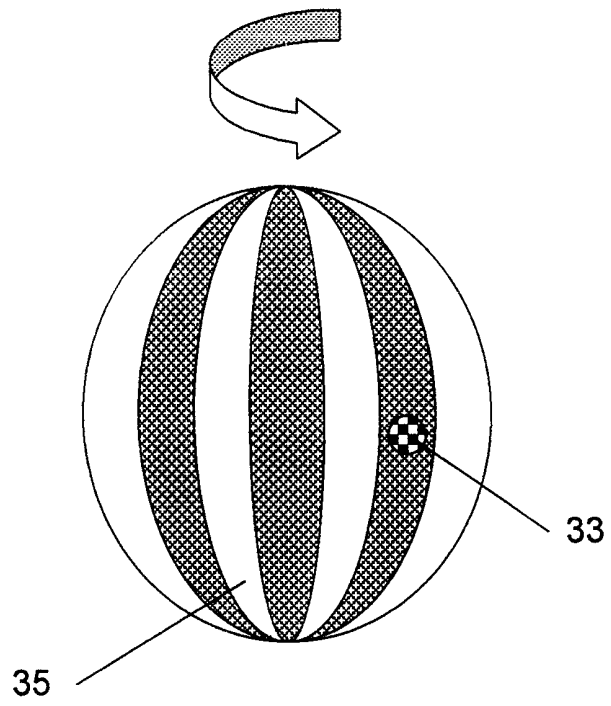**Fig. 4**

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6   G09B7/04   G06F15/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6   G09B   G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 5 870 731 A (TRIF IOAN ET AL) 9 February 1999 (1999-02-09) the whole document & CA 2 195 927 A (TRIF IOAN ET AL) 26 July 1997 (1997-07-26) ---	1,2,4,7, 9,11,25, 29,30, 34,35,42
A	US 5 696 885 A (HEKMATPOUR AMIR) 9 December 1997 (1997-12-09) the whole document ---	1-43
A	US 5 597 312 A (BLOOM CHARLES P ET AL) 28 January 1997 (1997-01-28) the whole document ---	1,7,8,42
A	US 5 506 937 A (COFFEY JOHN W ET AL) 9 April 1996 (1996-04-09) ---	1,4,27, 30,42

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| X | Further documents are listed in the continuation of box C. | | X | Patent family members are listed in annex. |

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 September 1999	29/09/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Gorun, M

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INTERNATIONAL SEARCH REPORT

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

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