DESCRIPTION

TITLE OF THE INVENTION: DEVELOPMENT MONTH AGE ESTIMATION DEVICE, DEVELOPMENT MONTH AGE ESTIMATION METHOD, AND NON-TRANSITORY COMPUTER-READABLE STORAGE MEDIUM

TECHNICAL FIELD

[0001]

The present invention relates to a development month age estimation device, a development month age estimation method, and a non-transitory computer-readable storage medium comprising a development month age estimation program for estimating a child's developmental age expressed in months (hereafter referred to as "development month age").

BACKGROUND ART

[0002]

It has been recognized that children, including infants and toddlers, exhibit individual differences in development, such as motor, language, cognitive, and emotional development. Parents and other caregivers may wish to compare a child’s developmental status with that of typically developing children of the same age in months (i.e., the same chronological age) in order to identify developmental deviations. Furthermore, accurately estimating a child's development month age, which represents the child's developmental status in terms of months, is important in the medical and educational fields.

[0003]

Examples of techniques for estimating a child’s development month age include a method in which an examiner (such as a medical or educational professional) uses tools to evaluate a child based on a checklist displaying a plurality of assessment items corresponding to the child’s developmental stage (e.g., actions or movements that a child of a target age is capable of performing), determines whether the child passes or fails each assessment item, plots

the assessment results on a graph, and estimates the child’s development month age (see Non-Patent Document 1).

PRIOR ART DOCUMENT (S)

NON-PATENT DOCUMENT(S)

[0004]

Non-Patent Document 1: Tojoji, Muneyoshi "The Tojoji Method: Analytical Developmental Assessment for Infants and Toddlers", Keio University Press, 2022 (Revised and Expanded Edition, First Edition, 7th Printing)

SUMMARY OF THE INVENTION

TASK TO BE ACCOMPLISHED BY THE INVENTION

[0005]

In addition to the method disclosed in Non-Patent Document 1, various evaluation methods for estimating a child’s development month age have been developed, each of which estimates development month age using its own set of assessment items. As a result, in such prior-art methods, a child's development month age must be estimated based on assessment items predefined for the respective estimation methods, regardless of whether those assessment items are optional for the child being evaluated. Therefore, techniques of the prior art make it difficult to estimate development month age using a standardized evaluation framework that allows assessment items to be selected more flexibly.

[0006]

In the prior art described in Non-Patent Document 1, because development month age is estimated by an examiner (i.e., a human) based on the assessment results, the estimated development month age may vary depending on the examiner's subjective judgment. Furthermore, human judgment is required for the final estimation of development month age, which makes it difficult to obtain assessment results quickly for rapid estimation.

[0007]

Through studies directed to solving these problems, the inventors have found that, by utilizing data on the pass rate for each assessment item (i.e., the proportion of children in a given age group who have achieved that item), highly objective estimates of development month age are obtained while allowing assessment items to be selected flexibly. In Non-Patent Document 1, pass rates for assessment items are used only for selecting and ordering the assessment items, and are not used as a basis for estimating development month age.

[0008]

The present invention has been made in view of the problems of the prior art, and a primary object of the present invention is to provide a development month age estimation device, a development month age estimation method, and a non-transitory computer-readable storage medium comprising a development month age estimation program that enable highly objective estimation of a child's development month age while allowing assessment items to be selected flexibly.

MEANS TO ACCOMPLISH THE TASK

[0009]

As a solution to the above-described task to be accomplished, an aspect of the present invention provides a development month age estimation device for estimating a child's development month age, comprising: a processor for estimating a development month age of a subject child based on assessment results for a plurality of assessment items; and a storage unit configured to store data regarding a continuous probability distribution for each of the plurality of assessment items, the continuous probability distribution representing pass rates as a function of month ages within a predetermined range, wherein the processor performs operations to: generate a development month age estimation function based on data regarding the continuous probability distributions for two or more subject items used in the assessment of the subject

child and selected from among the plurality of assessment items and assessment results for the subject items; estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and output the estimated development month age of the subject child.

[0010]

This configuration, in which a development month age estimation function is generated based on data regarding continuous probability distributions for assessed items and on assessment results for the items, and a development month age of a subject child is estimated based on the development month age estimation function, enables highly objective estimation of a child's development month age while increasing flexibility in selecting assessed items.

[0011]

The above-described development month age estimation device may be further configured such that the processor performs operations to: obtain, for each of the plurality of assessment items, data indicating a plurality of month ages and pass rates corresponding thereto; and generate data regarding the continuous probability distributions based on the data on the pass rates.

[0012]

This embodiment enables data regarding the continuous probability distributions to be easily obtained based on the data on the pass rates corresponding to the respective month ages.

[0013]

The above-described development month age estimation device may be further configured such that the processor performs operations to: determine two parameters of the probability density function of a beta distribution based on the data on the pass rates; and generate data regarding the continuous probability distributions based on a cumulative distribution function obtained by integrating the probability density function of the beta

distribution.

[0014]

This embodiment enables data regarding the continuous probability distribution suitable for estimating a child's development month age to be obtained based on the probability density function of a beta distribution.

[0015]

The above-described development month age estimation device may be further configured such that the processor performs operations to: define an age interval for the data on the pass rates for each of the plurality of assessment items; and convert the age interval to a range from 0 to 1.

[0016]

This embodiment enables data regarding the continuous probability distribution to be properly obtained based on the probability density function of a beta distribution.

[0017]

The above-described development month age estimation device may be further configured such that the processor performs operations to: set, for each of the subject items, a probability function for the pass rates based on the data regarding the continuous probability distribution and the assessment results, wherein the development month age estimation function includes the product of the probability functions for the subject items.

[0018]

This embodiment enables a subject child's development month age to be easily estimated based on data regarding the continuous probability distributions for the respective subject items and the assessment results.

[0019]

The above-described development month age estimation device may be further

configured such that the development month age estimation device further comprises a display unit for displaying the estimated development month age.

[0020]

This embodiment enables users of the development month age estimation device to easily verify the results of development month age estimation.

[0021]

As a solution to the above-described task to be accomplished, another aspect of the present invention provides a development month age estimation method for estimating a child's development month age, the method comprising causing a development month age estimation device to perform estimation operations for estimating a development month age of a subject child by using a plurality of assessment items, wherein the estimation operations include operations to: generate a development month age estimation function based on data regarding continuous probability distributions for two or more subject items used in the assessment of the subject child and selected from among the plurality of assessment items and assessment results for the subject items; estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and output the estimated development month age of the subject child.

[0022]

This configuration, in which a development month age estimation function is generated based on data regarding continuous probability distributions for assessed items and on assessment results for the items, and a development month age of a subject child is estimated based on the development month age estimation function, enables highly objective estimation of a child's development month age while increasing flexibility in selecting assessed items.

[0023]

As a solution to the above-described task to be accomplished, yet another aspect of the

present invention provides a non-transitory computer-readable storage medium comprising a development month age estimation program that causes a computer to perform estimation operations for estimating a development month age of a subject child by using a plurality of assessment items, wherein the estimation operations include operations to: generate a development month age estimation function based on data regarding the continuous probability distributions for two or more subject items used in the assessment of the subject child and selected from among the plurality of assessment items and assessment results for the subject items; estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and output the estimated development month age of the subject child.

[0024]

This configuration, in which a development month age estimation function is generated based on data regarding continuous probability distributions for assessed items and on assessment results for the items, and a development month age of a subject child is estimated based on the development month age estimation function, enables highly objective estimation of a child's development month age while increasing flexibility in selecting assessed items.

EFFECT OF THE INVENTION

[0025]

The above configurations of the present invention enable highly objective estimation of a child's development month age while increasing flexibility in selecting assessment items.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

[Figure 1] Figure 1 is a diagram showing a general configuration of a development month age estimation device according to an embodiment of the present invention;

[Figure 2] Figure 2 is an explanatory diagram showing an example of pass-rate data

for a plurality of assessment items;

[Figure 3] Figure 3 is an explanatory diagram of an example including (A) a pass-rate probability distribution and (B) a cumulative pass-rate distribution;

[Figure 4] Figure 4 is an explanatory diagram showing an example of month age interval settings for each of the assessment items;

[Figure 5] Figure 5 is an explanatory diagram showing an example of an assessment item confirmation screen; and

[Figure 6] Figure 6 is an explanatory diagram showing an example of a pass-rate probability distribution generated based on the development month age estimation function.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

[0027]

In the following description, embodiments of a development month age estimation device, a development month age estimation method, and a development month age estimation program will be described with reference to the drawings.

[0028]

As shown in Figure 1, a development month age estimation system 1 includes a development month age estimation device 2 for estimating a child’s developmental age in months, and a user terminal 4 that is communicatively connected to the development month age estimation device 2 via a communication network 3, such as the Internet.

[0029]

The development month age estimation device 2 includes a computer configured to execute a processing operation for estimating a child’s development month age (hereinafter referred to as "development month age estimation operation"). In the present embodiment, the development month age estimation device 2 primarily comprises a server that executes an operation to estimate a child’s development month age in response to a request from a client

used by a user. (In the present embodiment, the client is a user terminal 4.)

[0030]

The development month age estimation operation is performed by the development month age estimation device 2 based on data on assessment results for the respective assessment items conducted in the past and on assessment results for items used in the current assessment of a subject child (hereinafter referred to as "subject items"). An examiner can conduct the assessment for the subject items using the same methods as any of the known assessment methods.

[0031]

The data on past assessment results is obtained for assessment items used in the estimation of a child's development month age. In the development month age estimation system 1, the assessment items used in estimation of development month age may include, for example, those adopted in Non-Patent Document 1. However, the development month age estimation system 1 is not limited to this configuration; the system may use any assessment items adopted in other well-known assessment methods (e.g., W. K. Frankenburg, M.D., "DENVER II: The Denver Developmental Screening Test," Japan Society of Child Health, 2016 (2nd ed., 2nd printing); Junko Nakamura, Ichiro Okawa, Rie Nohara, and Nanami Serizawa, "Tanaka-Binet Cognition Test V," Taken Publishing Co., Ltd., 2003; Harutaro Suzuki, "Revised Edition: Suzuki-Binet Cognition Test," Furuichi Publishing, 2007; New Edition K-Type Developmental Assessment Research Group (eds.), "New Edition K-Type Developmental Assessment Method 2001 Edition," Nakanishiya Publishing, 2008; Makoto Tsumori and Kyoko Inage, "Diagnostic Methods for Psychomotor Development in Infants and Toddlers," Dainippon Tosho, 1961; Misato Tanaka et al., "Revised Voluntary Motor Development Test," Voice and Language Medicine, 1990, 31: pp. 172–185; and Tsuneo Satake, "Question-Response Relationship Test," Escor, 1997).

[0032]

In particular, the development month age estimation system 1 preferably uses assessment items for which the reliability of pass-rate data (e.g., the percentage of children of a certain age who have achieved the assessment item) across a plurality of age groups has been established. Furthermore, when pass-rate data for a new assessment item is obtained across a plurality of age groups, the development month age estimation system 1 may adopt the new assessment item.

[0033]

In the present embodiment, the term "child" or "children" primarily refers to infants and preschoolers, as well as school-age children, in a range of chronological age from 0 to 12 years. However, subjects of development month age estimation performed using the systems, devices, methods, and programs of the present disclosure are not limited to such children and can be individuals of any chronological age (including adolescents and adults).

[0034]

The user terminal 4 may be an information processing device with communication capabilities, such as a smartphone, tablet, or PC, used by a user. Examples of users may include medical or educational professionals, but are not limited to such professionals; users may also be individuals other than such professionals (e.g., a child’s family). Furthermore, although only one user terminal 4 is shown in Figure 1, the development month age estimation system 1 may include two or more user terminals.

[0035]

In the present embodiment, the system is configured such that the user terminal 4 causes the development month age estimation device 2 to execute the development month age estimation operation; however, the system is not limited to this configuration, and the user terminal 4 may itself function as the development month age estimation device (i.e., to execute

the development month age estimation operation). In other words, the development month age estimation device 2 is not limited to a server and may be configured using an information processing device such as a smartphone, tablet, or PC, similar to the user terminal 4. In this case, the development month age estimation device 2 does not necessarily need to be connected to a communication network and may be operated directly by a user. Furthermore, the development month age estimation operation performed by the development month age estimation system 1 may be implemented by a cloud (i.e., a collection of virtual resources and services).

[0036]

The development month age estimation device 2 includes a communication unit 11, an input unit 12, a display unit 13, a storage unit 14, and a control unit 15.

[0037]

The communication unit 11 includes an antenna and communication circuits, and communicates with other devices (such as the user terminal 4 in this case) via the communication network 3 using wireless or wired communications in accordance with a known communication protocol.

[0038]

The input unit 12 includes a conventional input device (such as a keyboard) for entry of operation commands and other input data into the development month age estimation device 2. However, when operation commands and other input data are entered into the development month age estimation device 2 from another device (such as the user terminal 4), the input unit 12 may be omitted.

[0039]

The display unit 13 includes a known device (e.g., a display device such as an LCD) for displaying (i.e., outputting) information used by the development month age estimation

device 2 and information generated by the development month age estimation device 2. However, when information from the development month age estimation device 2 is output to another device (e.g., the user terminal 4), the display unit 13 may be omitted. Furthermore, such information may be output audibly, i.e., from a speaker (not shown).

[0040]

The storage unit 14 includes a storage device, such as a memory, for storing data and information necessary for processing operations performed by the development month age estimation device 2. The storage unit 14 is not necessarily provided integrally with the development month age estimation device 2 and may be instead comprised primarily of an external storage device connected to the development month age estimation device 2 via a network or any other communication medium. As described later, the storage unit 14 stores assessment item data 21, distribution function data 22, assessment result data 23, and development month age estimation function data 24, among other data.

[0041]

The control unit 15 includes one or more processors (such as a CPU or MPU). Through the execution of predetermined control programs (such as a development month age estimation program), the control unit 15 can perform processing operations necessary for development month age estimation. Furthermore, the control unit 15 can comprehensively control the operations of the development month age estimation device 2.

[0042]

The control unit 15 includes an assessment item data collection unit 31 configured to collect data regarding a plurality of assessment items conducted in the past from data stored in other databases (not shown) and store the data in the storage unit 14 as the assessment item data 21. As shown in Figure 2, for example, the assessment item data 21 includes data on pass rates for respective ages regarding the plurality of assessment items in the past.

[0043]

Figure 2 shows, for example, the pass rates for the assessment item No. 134, "Walking 2–3 steps." More specifically, Figure 2 indicates the following points as to “Walking 2–3 steps”: i.e., 44.2% of 11-month-old children have achieved this milestone (i.e., 44.2 % are capable of "Walking 2–3 steps"; 68.3% of 13-month-old children have achieved it; 89.5% of 15-month-old children have achieved it; and 98.0% of 17-month-old children have achieved it. The pass rates for other assessment items are similar to those for assessment item No. 134.

[0044]

As described above, the assessment item data 21 contains data regarding assessment items used in known assessment methods. The assessment item data 21 may include data obtained for new assessment items. At least a part of the assessment item data 21 stored in the storage unit 14 may be data entered beforehand by an administrator of the development month age estimation system 1 or any other personnel.

[0045]

In the control unit 15, a distribution function estimation unit 32 generates probability density functions and cumulative distribution functions for the pass rates of each assessment item based on the assessment item data 21.

[0046]

In the present embodiment, a beta distribution is used as the continuous probability distribution. The probability density function $f(x;\alpha,\beta)$ for the pass rate of each assessment item is expressed by Equation (1) below. As will be described in detail later, when the beta distribution is adopted, the age intervals for which pass rates have been obtained for the respective assessment items are transformed so as to correspond to the range of a random variable from 0 to 1.

[0047]

$$f(x;\alpha,\beta) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha,\beta)} \quad \cdots (1)$$

[0048]

where:

x: random variable ($0 \leq x \leq 1$); and

α, β: positive real numbers.

[0049]

However, the beta function B(α, β) in Equation (1) is expressed by the following equation.

[0050]

$$B(\alpha,\beta) = \int_0^1 t^{\alpha-1}(1-t)^{\beta-1}dt$$

[0051]

Furthermore, by integrating the probability density function f(x;α,β) of the beta distribution shown in Equation (1), the cumulative distribution function F(x;α,β) of the beta distribution is obtained, as expressed by Equation (2) below.

[0052]

$$F(x;\alpha,\beta) = \frac{\int_0^x t^{\alpha-1}(1-t)^{\beta-1}dt}{B(\alpha,\beta)} \quad \cdots (2)$$

[0053]

Based on the probability density function f(x;α,β) of the beta distribution, the distribution function estimation unit 32 can, as shown in Figure 3(A), properly control the location of the peak and the variance of the probability density function by setting the two parameters α and β. Furthermore, by determining the parameters α and β such that the beta distribution fits the pass rates of each assessment item in the assessment item data 21 (i.e.,

measured values obtained from past assessment results), the distribution function estimation unit 32 can obtain, as shown in Figure 3(B), an appropriate continuous probability distribution for the pass rates of each assessment item, represented by the cumulative distribution function $F(x;\alpha,\beta)$.

[0054]

For example, the distribution function estimation unit 32 can determine the parameters α and β such that the sum of squared residuals is minimized, the residuals being differences between the pass rates of each assessment item contained in the assessment item data 21 and the pass rates obtained from the cumulative distribution function $F(x;\alpha,\beta)$ at values of the random variable corresponding to the ages of the assessment item data 21.

[0055]

General-purpose scientific computing libraries may be used to determine the parameters α and β. For example, the parameters α and β may be determined using the BFGS method (Broyden-Fletcher-Goldfarb-Shanno method) or the L-BFGS-B method (Limited-memory Broyden-Fletcher-Goldfarb-Shanno with Box Constraints) implemented in the minimize function of the optimize module of the SciPy library for Python.

[0056]

Subsequently, the distribution function estimation unit 32 converts the values of the random variable in the range from 0 to 1 back into month-age intervals, thereby obtaining data for the cumulative distribution function $F(x;\alpha,\beta)$ of the pass rate using month age as the variable (i.e., data related to a continuous probability distribution).

[0057]

Data representing the probability density function $f(x;\alpha,\beta)$ and the cumulative distribution function $F(x;\alpha,\beta)$ of the beta distribution for each assessment item are sequentially stored in the storage unit 14 as the distribution function data 22.

[0058]

The distribution function estimation unit 32 can generate the above-described probability density function and cumulative distribution function when a new assessment item is added to the assessment item data 21 or when pass-rate data for an existing assessment item is updated.

[0059]

Next, with reference to Figure 4, a processing operation (hereinafter referred to as an "age conversion operation") for transforming, for each assessment item will be described. In the age conversion operation, age intervals in which significant changes in pass rates occur for each assessment item are transformed so as to correspond to values of a random variable in the range from 0 to 1. Note that, in addition to the processing method described below, age intervals may be determined using different methods, provided that they include all ages corresponding to the pass rate data and allow for the determination of valid parameters α and β. Furthermore, the age intervals may be redefined based on the previously obtained parameters α and β, and new parameters α and β may then be determined. These processing methods need not be uniformly applied to all assessment items. Different processing methods may be used for different assessment items, provided that age intervals can be defined such that sufficiently valid parameters α and β can be determined for each assessment item.

[0060]

For the age variable x, the distribution function estimation unit 32 first identifies the minimum value x_min and maximum value x_max in the data set for the assessment item being processed in the assessment item data 21. In the example of Figure 4, the data set for the assessment item is assumed to consist of two data points represented by the two white circles (○), each data point including an age and a pass rate. Similarly, the distribution function estimation unit 32 identifies the minimum value y_min and maximum value y_max of the pass

rate Y in the data set.

[0061]

Therefore, the distribution function estimation unit 32 defines a straight line passing through the points (x_min, y_min) and (x_max, y_max) in the XY plane, as illustrated by the solid line connecting the circles (○) and the dashed line extending therefrom in Figure 4, and determines the x-coordinates of the points at which the straight line intersects the lines y=0 and y=1, respectively, as represented by the squares (■) in Figure 4.

[0062]

Next, the distribution function estimation unit 32 calculates the X-coordinates of both endpoints of an interval W defined by the X-coordinates of the intersection points, and then calculates the X-coordinates of both endpoints of an interval 2W having twice the width of interval W and centered at the midpoint of interval W (see black circle (●) in Figure 4). Furthermore, the distribution function estimation unit 32 can determine, as the age interval subject to the age conversion operation for the target assessment item, the smallest interval that contains the X-coordinates and has endpoints are integers.

[0063]

Returning to Figure 1, in the control unit 15, the subject item setting unit 33 sets one or more subject items from among the assessment items included in the assessment item data 21. For example, the subject item setting unit 33 can set, as subject items, a plurality of assessment items selected by an examiner (e.g., through input from the user terminal 4).

[0064]

The development month age estimation device 2 can pre-calculate, for each of the assessment items, an age interval corresponding to the assessment item (i.e., an age interval in which a significant change occurs in the pass rate of the assessment item) based on the cumulative distribution function $F(x; \alpha, \beta)$ obtained for the assessment item. Furthermore, the

development month age estimation device 2 can generate an assessment item confirmation screen showing the age intervals calculated for the respective assessment items, as shown in Figure 5. When an examiner selects a subject item, the development month age estimation device 2 can transmit the assessment item confirmation screen to an external device (in this embodiment, the user terminal 4) and cause the screen to be displayed thereon.

[0065]

The assessment item confirmation screen displays a list of assessment items (see assessment items No. 313–382 in Figure 5) together with graphical representations of respective age intervals, which are, in this example, respective "age interval indication" bars representing the age intervals corresponding to the assessment items. Each age interval indication bar has a length corresponding to a predetermined pass-rate range (e.g., 2.5% to 97.5%), and includes a symbol (in this example, a black circle (●)) indicating the age at which the pass rate reaches its maximum value.

[0066]

An examiner can refer to the lengths of the age interval indication bars and the numerical values on the horizontal axis indicating age in months shown below the bars to determine the age interval corresponding to each assessment item (i.e., the age range within which the assessment item is valid for estimating the development month age). By checking the lengths of the age interval indication bars and the positions of the symbols indicating the ages at which the pass rates are highest, the examiner can determine whether the assessment items to be selected are appropriate for the current assessment. The examiner can set a desired assessment item (e.g., letters) as a subject item by performing a selection operation (e.g., a touch operation on a touch-panel display) on the assessment item confirmation screen. Alternatively, a preliminary evaluation may be performed using a similar method, and only assessment items determined to be valid may be used in subsequent processing.

[0067]

The subject items need not necessarily be selected by the examiner. For example, the subject item setting unit 33 may randomly select one or more subject items from among the assessment items included in the assessment item data 21. Alternatively, the subject item setting unit 33 may sequentially select appropriate subject items according to a predetermined algorithm based on the estimated development month age.

[0068]

In the control unit 15, the assessment result acquisition unit 34 acquires the respective assessment results for each subject item selected for the subject child. For example, an examiner can conduct an assessment for each subject item and input the assessment results from the user terminal 4 into the development month age estimation device 2. However, the assessment results may also be input by an automatic assessment device instead of the examiner. For example, the automatic assessment device may be equipped with a pre-trained model prepared for assessment and may obtain assessment results for each subject item based on video footage of the child’s actions. The assessment results obtained by the assessment result acquisition unit 34 are sequentially stored in the storage unit as assessment result data 23.

[0069]

The assessment result data 23 includes, for example, identifiers indicating whether each subject item has been "achieved" or "not achieved." The assessment result data 23 may further include identifiers indicating that a subject item has been partially achieved (i.e., a state in which it is difficult to determine whether the subject item has been fully achieved).

[0070]

In the control unit 15, a month age estimation function generation unit 35 generates a development month age estimation function based on cumulative distribution functions $F(x; \alpha, \beta)$ corresponding to two or more subject items used for assessing the child, and on assessment

results of the respective subject items.

[0071]

In generating the development month age estimation function, the distribution function Ei(m) representing the estimated pass rate for each subject item as a function of age in months is defined as follows.

[0072]

$$Ei(m) = 0 \ (m < M_{lower})$$
$$Ei(m) = F(x;\alpha,\beta) \ \ (M_{lower} \leqq m \leqq M_{upper})$$
$$Ei(m) = 1 \ \ (m > M_{upper})$$

[0073]

where:

m: month age (age in months);

M_{Lower}: the minimum value (integer value) of the month age within the age interval corresponding to each subject item; and

M_{Upper}: the maximum value (integer value) of the month age within the age interval corresponding to each subject item.

[0074]

The probability function Pi(m) corresponding to the assessment result is defined as follows. In some cases, the "partially achieved" assessment result is not considered.

[0075]

Not Achieved	$Pi(m) = 1 - Ei(m)$
Partially Achieved	$Pi(m) = \sqrt{Ei(m) \times (1 - Ei(m))}$
Achieved	$Pi(m) = Ei(m)$

[0076]

where:

i: the index number for each subject item.

[0077]

The development month age estimation function P(m) can be expressed using the probability function Pi(m) as described above, based on Bayes' theorem, as shown in Equation (3) below.

[0078]

$$P(m) = \frac{P1(m) \times P2(m) \times \cdots \times Pn(m)}{\int_{M_{lower}}^{M_{upper}} P1(m) \times P2(m) \times \cdots \times Pn(m)\, dm} \quad \cdots (3)$$

[0079]

where:

n: number of subject items;

M_{Lower}: the minimum value (integer value) of the month age within the age interval corresponding to each subject item; and

M_{Upper}: the maximum value (integer value) of the month age within the age interval corresponding to each subject item.

[0080]

In the control unit 15, a development month age estimation unit 36 can estimate the development month age of the subject child based on the mode of the probability distribution represented by the development month age estimation function P(m) (i.e., the conditional probability of assessment results for predetermined respective assessment items corresponding to each month age). In the probability distribution represented by the development month age estimation function P(m), a peak (i.e., a mode) appears, as illustrated in Figure 6. The development month age estimation unit 36 can estimate the development month age of the subject child based on the month age corresponding to the peak. When presenting the estimated development month age, the development month age estimation unit 36 may output the month age corresponding to the peak, or may output a predetermined range including the month age

corresponding to the peak (for example, a range having the month age corresponding to the peak as its median).

[0081]

The location of the peak of the probability distribution represented by the development month age estimation function P(m) depends only on the likelihood function corresponding to the numerator of Equation (3). Therefore, the development month age estimation function P(m) of Equation (3) may be represented solely by the likelihood function, with the denominator omitted.

[0082]

When the assessment results for all subject items are "achieved," neither the mode nor the upper limit of the estimated development month-age range can be obtained; however, the lower limit of the estimated development month age range can be obtained. Similarly, when the assessment results for all subject items are "not achieved," neither the mode nor the lower limit of the estimated development month-age range can be obtained; however, the upper limit of the estimated development month age range can be obtained. In either case, the development month age estimation unit 36 can output the above results to the display unit 13 or the user terminal 4, but it is also acceptable to output an error message indicating that an appropriate estimation result could not be obtained.

[0083]

The development month age estimation unit 36 may output an error message to the display unit 13 or the user terminal 4 upon determining that the assessment results contain a contradiction. For example, the development month age estimation unit 36 can determine that a contradiction exists when, among the assessment items shown in Figure 5, the assessment result for a subject item corresponding to a particular age interval is "not achieved," while an assessment item corresponding to a higher age interval is evaluated as "achieved" (Figure 5).

[0084]

At least part of the functions of the units 31 to 36 included in the control unit 15 may be implemented by one or more processors executing predetermined control programs. Furthermore, the control unit 15 comprehensively controls the operation of the development month age estimation device 2.

[0085]

In the development month age estimation system 1 having the above-described configuration, an examiner can access the development month age estimation device 2 from the user terminal 4 and perform a development month age estimation operation. During the development month age estimation operation, the examiner can input (i.e., select) a desired assessment item (i.e., a subject item) from the user terminal 4 to the development month age estimation device 2. Furthermore, the examiner can input an assessment result for each subject item from the user terminal 4 to the development month age estimation device 2. While sequentially conducting the assessment for a plurality of subject items to the subject child (i.e., while sequentially obtaining assessment results for the respective subject items), the examiner can input the assessment results to the development month age estimation device 2.

[0086]

Once the examiner has entered the assessment results, the development month age estimation device 2 generates a development month age estimation function based on cumulative distribution function data $F(x;\alpha,\beta)$ for the respective subject items and the assessment results for the respective subject items. The development month age estimation device 2 then estimates the development month age of the subject child based on the mode of the probability distribution represented by the generated development month age estimation function. The development month age estimation device 2 then transmits the estimated development month age to the user terminal 4 in order to display the estimated development

month age on a display of the user terminal 4.

[0087]

In some cases, when the user terminal 4 functions as a development month age estimation device, all of the above-described development month age estimation operations may be performed by the user terminal 4.

[0088]

Thus, the development month age estimation system 1 generates a development month age estimation function P(m) based on data from the cumulative distribution function $F(x;\alpha,\beta)$ of pass rates with development month age as a variable, as well as the assessment results for each of the subject items, and then estimates the development month age of the subject child based on the development month age estimation function, thereby enabling highly objective estimation of a child's development month age while increasing flexibility in selecting assessed items.

[0089]

While specific embodiments of the present disclosure are described herein for illustrative purposes, the present disclosure is not limited to those specific embodiments. In the development month age estimation device, development month age estimation method, and a development month age estimation program according to the above-described embodiment, not all of the elements thereof are essential, and at least the skilled person would be able to make appropriate modifications to, additions to, or omissions of such elements, without departing from the scope of the present invention.

[0090]

For example, the term "age in months" or "month age" used in the present disclosure to indicate a child's developmental stage does not necessarily have to be expressed in months; for example, the age may be expressed in years or in a combination of years and months.

Furthermore, the age interval does not necessarily have to be an integer value and may include decimal values. Additionally, in the present embodiment, a beta distribution is used as a continuous probability distribution for the pass rates of the respective assessment items. However, other probability density functions may also be used, provided that the parameters defining the distribution can be uniquely and appropriately determined from existing pass-rate data.

GLOSSARY

[0091]

1	development month age estimation system
2	development month age estimation device
3	communication network
4	user terminal
11	communication unit
12	input unit
13	display unit
14	storage unit
15	control unit
21	assessment item data
22	distribution function data
23	assessment result data
24	development month age estimation function data
31	assessment item data collection unit
32	distribution function estimation unit
33	subject item setting unit
34	assessment result acquisition unit

35 month age estimation function generation unit

36 development month age estimation unit

CLAIMS

[Claim 1]

A development month age estimation device for estimating a child's development month age, comprising:

a processor for estimating a development month age of a subject child based on assessment results for a plurality of assessment items; and

a storage unit configured to store data regarding a continuous probability distribution for each of the plurality of assessment items, the continuous probability distribution representing pass rates as a function of month ages within a predetermined range,

wherein the processor performs operations to:

generate a development month age estimation function based on data regarding the continuous probability distributions for two or more subject items used in the assessment of the subject child and selected from among the plurality of assessment items and assessment results for the subject items;

estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and

output the estimated development month age of the subject child.

[Claim 2]

The development month age estimation device as claimed in claim 1, wherein the processor performs operations to:

obtain, for each of the plurality of assessment items, data indicating a plurality of month ages and pass rates corresponding thereto; and

generate data regarding the continuous probability distributions based on the data on the pass rates.

[Claim 3]

The development month age estimation device as claimed in claim 2, wherein the processor performs operations to:

determine two parameters of the probability density function of a beta distribution based on the data on the pass rates; and

generate data regarding the continuous probability distributions based on a cumulative distribution function obtained by integrating the probability density function of the beta distribution.

[Claim 4]

The development month age estimation device as claimed in claim 3, wherein the processor performs operations to:

define an age interval for the data on the pass rates for each of the plurality of assessment items; and

convert the age interval to a range from 0 to 1.

[Claim 5]

The development month age estimation device as claimed in claim 1, wherein the processor performs operations to:

set, for each of the subject items, a probability function for the pass rates based on the data regarding the continuous probability distribution and the assessment results,

wherein the development month age estimation function includes the product of the probability functions for the subject items.

[Claim 6]

The development month age estimation device as claimed in claim 1, further comprising a display unit for displaying the estimated development month age.

[Claim 7]

A development month age estimation method for estimating a child's development month age, the method comprising causing a development month age estimation device to perform estimation operations for estimating a development month age of a subject child by using a plurality of assessment items,

wherein the estimation operations include operations to:

generate a development month age estimation function based on data regarding continuous probability distributions for two or more subject items used in the assessment of the subject child and selected from among the plurality of assessment items and assessment results for the subject items;

estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and

output the estimated development month age of the subject child.

[Claim 8]

A non-transitory computer-readable storage medium comprising a development month age estimation program, wherein the development month age estimation program causes a computer to perform estimation operations for estimating a development month age of a subject child by using a plurality of assessment items, wherein the estimation operations include operations to:

generate a development month age estimation function based on data regarding the

continuous probability distributions for two or more subject items used in the assessment of the subject child and selected from among the plurality of assessment items and assessment results for the subject items;

estimate the development month age of the subject child based on a mode value of a pass-rate distribution represented by the development month age estimation function; and

output the estimated development month age of the subject child.