Advances in Anthropometric Accounting for Ear Digital Modeling

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Abstract

Anthropometry for general digital human modeling (DHM) may be enhanced and improved in clarity, accuracy of text and illustrations by adopting analogies of standard concepts for business accounting terminology and data. Analogs and differences between the two systems are described with examples. These procedures can aid organizing, publishing and applying data on anthropometric dimensions, especially for the complex shapes of human ears. Implications of these apparently simple practices have led to far-reaching benefits regarding text and illustrations in documentation. They can benefit anthropometric surveys, reports, data documents and software for computer aided design (CAD) using digital human models. Also, many additional advances beyond double entry book keeping concepts have been suggested by applying basic engineering graphics practices to deal with the unusual challenges of wide variability in shape and size of human ears. These include (a) extensive new titles and abbreviations for previously numbered points, (b) new titles, abbreviations and descriptions for some newly invented points that needed correction and formal recognition, (c) new concepts for formally recognizing reference lines, planes and curved surfaces as end conditions (herein called delimitations) together with their titles and abbreviations, (d) inclusion of callouts for points, lines, and surfaces in two orthogonal illustrations for dimensions and for delimitations and (e)) new classifications and codes for path constraints for dimensions. The latter provide compact notation to distinguish between straight line and curved dimension, especially if they have the same origins and terminations. Also included are new concepts for reference view planes for ears. These include an Ear Primary View Plane (parallel to ear width and length) and a set of closely related, cross-section planes that are perpendicular to it. The latter aid depiction of true lengths of dimensions relative to ear figures that are commonly published and avoid certain difficulties of attempts to use standard anthropometric principal planes and axes for describing and illustrating measurements. Such advanced accounting procedures offer further benefits for creating multi-population databases, accurately retrieving data from databases and applying data to CAD analyses and digital modeling. The revelations of this document can fill a need to improve all ear anthropometric survey dimension selections, definitions, illustrations in many related fields to facilitate digital modeling, and many articles about plastic surgery, forensics, health and nutrition, and design requirements for ear-related devices, such as ear buds, earphones, ear muffs and other protective gear.

1. Introduction

“Anthropometric accounting” is a new way of thinking that is a lot like business accounting in the way that it helps to keep track of dimensions and their origins and terminations. This presentation points out analogs of concepts between business accounting practices and recommended advances in practices for accounting of anthropometric dimensions. It is argued that such practices can have significant benefits for thought process and information organization that may improve anthropometric practices. Specific results to date include discovery of errors, revolutionary extensions of landmark concepts to include lines and surfaces, and significant enhancements of illustration formats related to anthropometric research and database development. It is shown that these accounting approaches may be especially useful and beneficial for the future measurement and reporting of complex shapes of human ears and for creating new, more accurate digital models of them as compared to past attempts (e.g., Davison, 2003): Recent studies of ear anthropometry also have contributed several new insights about terminology and illustration formats for anthropometry in general. In particular, it has suggested new notation methods and illustration concepts for dealing with authors’ descriptions of ear dimensions and locations of landmark points and reference lines as if they were printed on a plane surface instead of located in three-dimensional space. For general anthropometry and for ears, it offers a tabular method for describing curved dimensions that pass through several points along their path. Examples of some new format approaches and a summary “road map” of ear anthropometry (equivalent to a visual ledger) are included.

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2. Business and anthropometric accounting analogies and differences

Some of the simpler analogies between business accounting practices and anthropometric accounting are introduced in Table 1.

Table 1. Accounting Analogies.

Business Accounting	Anthropometric Accounting
$ Transaction	Dimension
Debit	Origin (Start)
Credit	Termination (End)
Account Title and Number	Landmark Title and Abbreviation or maybe Number.
Chart of Accounts	List of Landmarks
Medium of Exchange (check, wire, cash)	Orientation, Path of Dimension (curved, straight, 2-D or 3-D)

A business transaction defines and describes movement of money from one account to another. The analog in anthropometric accounting is a dimension, which may be thought of as the description of a distance from one point, line or surface to another point, line or surface. Measuring the distance between the two end conditions (as by moving a branch of a caliper, for example) is a conceptual form of movement, which may start from a designated "origin" and end at a designated "termination." Of course, the direction of "movement" is arbitrary.

In their simplest, classical form, the end conditions are points in three-dimensional space, on the surface of the human body (Martin, 1914), which are often called measuring points or landmarks. They are, in some respects, analogous to the debit and credit of double entry business book keeping. For every transaction, there must be a debit account and a credit account. Each account has a title and a number.. For every anthropometric distance measurement, there must be a start point and an end point. These end conditions each should have an unique title and, in classical anthropometry, also had an assigned abbreviation, consisting of an acronym for the title in lower case font (Martin, 1914, Jones, 1929, Madzharov, 1989a) that could be used in a journal of measurements.

Unfortunately, no abbreviations have been published for many points and other end conditions in modern U. S military anthropometry and many other anthropometric documents Therefore, to assure that there are actually unique abbreviations to be used for clearly and briefly identifying dimensions, a great many new abbreviations must be invented to accomplish the intentions and gain benefits of anthropometric accounting. Further, the concepts of points must be extended to provide titles and abbreviations for recognized reference lines (straight and curved) and for reference surfaces (plane and curved) that have been used in applied anthropometry.

Other tables of information in business accounting also have counterparts in anthropometric accounting, as will be shown later.

2.1. Differences in anthropometric accounting

Anthropometric accounting also must deal with several important differences from business accounting such as listed in Table 2. For example, instead of single monetary values for population samples, there are statistical variables, such as means, standard deviations, coefficients of variation, and percentiles involved in data on each dimension distribution (Anthropology Research Project Staff, 1978): . Ratios between length and width or other dimensions also may be included. Comparisons across two or more dimensions may involve coefficients of correlation (Cheverud et al., 1990), (Roebuck, 1995): In general, anthropometric dimension descriptions should always be supported by clear illustrations of individual dimensions, and preferably by a summary visual index of dimensions for a large documents. Line drawings are readily reproduced by copy scanning and copy machines, but photographs may be more helpful in showing contours and use of instruments. Well-prepared documents also should have graphic presentations for each end condition (delimitation), such as landmark points, lines and surfaces as well as proper use anatomical terms.

Table 2. Significant Differences In Scope, Content and Goals of Anthropometric Accounting as Compared to Business Accounting.

Anthropometric Accounting	Business Accounting
Statistical Data: Means, S.D., Percentiles, Correlations, Index and Ratios	Single-value money amounts for business transactions
Illustrations: Paper and CAD Drawings, Photos, Laser Scans, Digital Human Models (individuals and groups) Individual dimensions and visual Indexes - Individual landmark points, lines and surfaces and visual indexes of landmarks, lines, surfaces	None Required for business accounting journals and ledgers, income statements and balance sheets.
Anatomical, Dimensional Terminology: Titles, abbreviations, descriptions.	Goods and services, income and expense, profit and loss terminology
Procedural Goals: Completeness and accuracy of databases for comparisons across populations and reliability of ergonomic design requirements	Analysis of profits and losses for enterprises):

The basic goals of anthropometric accounting are obviously different from calculating profit and loss in business accounting. Anthropometry goals include planning information for plastic surgery, evaluation information for forensics, design requirements for workspace, clothing and personal equipment, and health analysis. Databases are needed for summarizing and comparing dimensions (Mollard, Ressler and Robinette, 2006): For workspace design, information on reach, vision angles through windows or toward displays, and clearances are often desired.

3. General anthropometry problems and advanced solutions

Ideas about anthropometric accounting for ears have evolved from extended studies by the author concerning problems and possible solutions for general anthropometry over more than four decades. Some of those problems are displayed in Table 3.

Table 3. General Anthropometry Problems and Advanced Solutions.

Problems	Proposed Solutions
Different names for same dimensions, different dimensions with same name, different abbreviations for same landmark in literature. Some measurements on left side, others on right side. Often not declared in titles or landmark abbreviations	Extensive, careful, historical research, compilation of illustrated dictionaries with synonyms, two orthogonal view illustrations for both end conditions (delimitations) and dimensions.
Classical and modern engineering (ergonomic) terminology in anthropometric literature.	Revise word order of classic titles to shorten and simplify (e.g., “Ear Length” vs. “Physiognomic Length of the Ear”): and aid alphabetical listing by anatomical region (not by “length” or breadth”)
Incomplete listing of titles, abbreviations, or descriptions of landmark points, no formal recognition of lines and surfaces for some dimensions end conditions	Provide two orthogonal views of dimensions and end conditions.
Some measurements on left side, others on right side. Often not declared in titles or landmark abbreviations	Always proof read (by different persons) comparing text with illustrations! (“Old school” approach – still works)
Errors in Illustrations: discrepancies from text descriptions of dimensions.	Provide guidelines document for future applications

Advances toward solutions of these problems are listed in the right column. Some of the proposed advances are clearly quite high level and simply good technical and editorial sense. However, some very specific documents are in work or already completed to distill the advice into extensive recommendations about recommended titles, abbreviations, illustrations and formats that are expected to become valuable assets for persons planning new surveys, organizing and editing data

for new databases and performing analysis of comparability of existing data. For example, an illustrated dictionary of anthropometric point landmarks, lines and surfaces for end conditions is in draft form (Roebuck, 2004): . It presents, in a standard format, about 400 recommended titles (and synonyms) associated abbreviations for end conditions, two orthogonal views (and some perspective views) on which locations of the noted end condition are pointed out, text descriptions that included variables such as posture and muscle tension that may affect location of the item of concern. For persons planning to name new dimensions, it offers a chance to check for potential duplications of previously published titles and abbreviations and thus avoid potential confusion in the future.
Also resulting from the studies is a guidelines document draft that offers recommended formats for word order, content of descriptions, worksheets for development trials of titles, abbreviations and recommended formats for illustrations and their markings (Roebuck, 2011b): This document considers both dimensions and end conditions (points, lines and surfaces), which are called by a new, collective title: “Anthropometric Dimension Delimitations” Recommendations for coding various dimension path constraints are also included.

4. Breakthrough advanced concepts that can benefit all anthropometry

A revolutionary approach to improving anthropometric terminology is recommended It involves expanding the past classical approaches to identifying anthropometric end conditions, from a limited focus on points marked on the body to include all reference lines, planes and curved surfaces where dimensions can start or end. Successful accomplishment of such work would provide a consistently formatted set of unique abbreviations that would facilitate the accounting procedures noted in Table 1.
Further, to Implement the general concept there are new recommendation for slight modifications to abbreviation symbology. Specifically these assign new meaning to enclosing parentheses ( ) so they are used only for locations on the human subject. In contrast, brackets [ ] are used only for surrounding equipment and structures such as seat pans and back supports, walls, floors, control panels and controls, near a person in either a laboratory or workspace situation.
In addition, the concept of type of abbreviation is formalized to include titles and abbreviations for each end condition. In the recommended system, upper case letters are used to distinguish end conditions that involve lines, planes or curved surfaces. Lower case letters are continued for points, so as to be “backward compatible” with previous publications in the classical anthropological literature for about 100 years. It is strongly recommended that such abbreviation symbols be added as suffixes to all titles of dimensions in survey reports and database tables. To be effective, each abbreviation, and preferably each title of an end condition should be unique, not used for more than one end condition. Admittedly, other systems exist for designating points, such as that of van Sint Jan (2007), who uses upper case letters for points located on the bony structure of the body.
Another unusual new concept is included, the use of UPPER CASE letter and number combination codes to identify the orientation and shape of distances between the end conditions for dimensions. Details are shown in a guidelines document referred in the references.

5. Special challenges of ear anthropometry and their solutions

Specific challenges of ear anthropometry for digital modeling and proposed solutions are summarized in Table 4. Ears are perhaps the body parts most variable in shape and size, with many features often missing or rudimentary or greatly enlarged (Alvord and Farmer ,1997), (Gray, and Lewis, 1944):. They are individual in nature like fingerprints and often have contributed to solving criminal activity. Average dimensions are different between genders, across ethnic and genetic backgrounds (Dolnick, 2011), age groups and differing health status and nutrition in different populations.
Lack of a specified view direction related to ear figures seems to be common among the majority of ear anthropometry documents, but it may be readily fixed by future authors, and should be Among the few notable exceptions are those of Alexander and Laubach (1968) and Liu (2008): These involved photos taken while the line of sight was perpendicular to the head midsagittal plane.
Most documents contain data on only a few dimensions, and these are often not well connected so as to form a coherent set of data suitable for digital modeling (Jung and Jung, 2003), (Liu, 2008):.
Dimensions are often not connected to each other or width related to ear long axis location, thus making very difficult the development of comprehensive systems for coordinates for digital human modeling.
These issues are of concern for design of hearing aids, ear buds, ear phones, ear muffs, ear plugs, spectacles, protective helmets and other surrounding protective gear, and even jewelry of many types

(Roebuck and Casali, 2011): Most sources of ear anthropometry data are published in the literature of plastic surgery, health studies, and anthropology, few in ergonomic-related articles (Roebuck, 2010), (Jung and Jung, 2003):
Because ear anthropometry surveys have been accomplished in many different nations, the literature contains documents written in many different languages. This situation poses problems of translation into the language of fluency of any researcher, another barrier to compilation of the data into a comprehensive database.

Table 4. Ear anthropometry challenges and advanced solutions.

Problems	Advanced Solutions
Lack of view direction information Use photographs or carefully draw ear figures using photographs as guides.	Define view directions for all ear figures including main views and cross-sections.
Few world-wide standards for either terminology or formats for illustration involving ear anthropometry. Titles in different publications are often quite different for dimensions and landmarks	Apply many of the suggested advances in this article to develop standards, including appending abbreviations for end conditions and path constraints (delimitations) for dimension titles.
Idealized, schematic and distorted shapes of ear figure drawings (Jones, 1929).	Use photographs or carefully draw ear figures using photographs as guides
One view where two are needed to show 3-D location, shapes.	Provide two orthogonal views and auxiliary views and cross-sections in illustrations.
Many errors in titles and illustrations compared to historical meaning, some errors in point abbreviations, discrepancies from text .	Review historical literature and develop corrections to text and illustrations for use in future database documents, survey reports, guidelines documents, illustrated dictionaries and technical articles.
Unlike Stature, Ear Length generally increases during old age (Roebuck and Casali, 2011) Even the ear canal diameter may change with age (Thomas, Wright and Casali,1994). .	Compile available data and compare for age groups trends. Larger databases needed for world wide populations. Work in progress by Roebuck Research and Consulting.
Few or no data on ear dorsal surface shapes in most surveys, and not much on thickness except for ear lobes.	Work planned to make appropriate measurements on ear castings, recommend new measurements for future surveys.
Lack of percentiles, correlations and ratios in most plastic surgery literature.	Apply statistical derivation and estimation formulas to combinations and comparisons of available data. Write technical articles explaining values of such data for other disciplines.
Major doctoral thesis of Dr. M. Madzharov (1986): unpublished extracts on ear anthropometry in Bulgarian and Latin.	Collaboration on translation into technical English and publishing currently in work. Dimension descriptions completed.

6. Major innovative concepts for illustrations and terminology

Two new types of auxiliary view planes are recommended for ear anthropometry . These planes imply a specific, precise direction of view toward the ear (perpendicular to the view plane), often missing in ear anthropometry literature. Important results from employing these new view concepts include (1) ease of description of orientation (toward or away from the view plane) and (2) ease of displaying (and describing) true scaled length of many dimensions, especially those not precisely parallel to the Ear Primary View Plane

6.1. Ear Primary View Plane concept

After struggling with the huge variability of ears involving differing shapes of features and differing angles of pitch, roll and yaw, a breakthrough concept was developed for an auxiliary view plane for each ear to simplify discussion of orientation of dimensions and features. These view planes are defined as precisely oriented parallel to the individual's left or right ear length and width. Normally, such plane are used for an orthographic projection of the nearby ear shape. The projected figure may

appear as a two-dimensional hard copy illustration in publications or as a CAD drawing on a computer monitor screen. An illustration of this type of view plane is shown in Figure1. For the left ear, the concept offers a reasonable, simplifying explanation for most of the two major, introductory ear figures shown in the Madzharov thesis extracts. Similar figures are commonly shown in other articles on ear anthropometry as a starting figure for dimension descriptions. Because of their importance in ear anthropometry, these planes are herein named as Ear Primary View Plane, Left or Right. which are abbreviated (EP.VP)L or R to distinguish between the left or right ears. Such planes are presumed to be located outside the ear (perhaps two centimeters), because the length and width dimensions are often not in the same 3-D plane in real subjects. For ears, they should be considered equivalent to the three Principal Planes for whole-body anthropometry (Sagittal, Coronal [Frontal), and Transverse). These planes imply a specific, precise direction of view toward the ear (perpendicular to the view plane), often missing in ear anthropometry literature, as noted in Table 4.

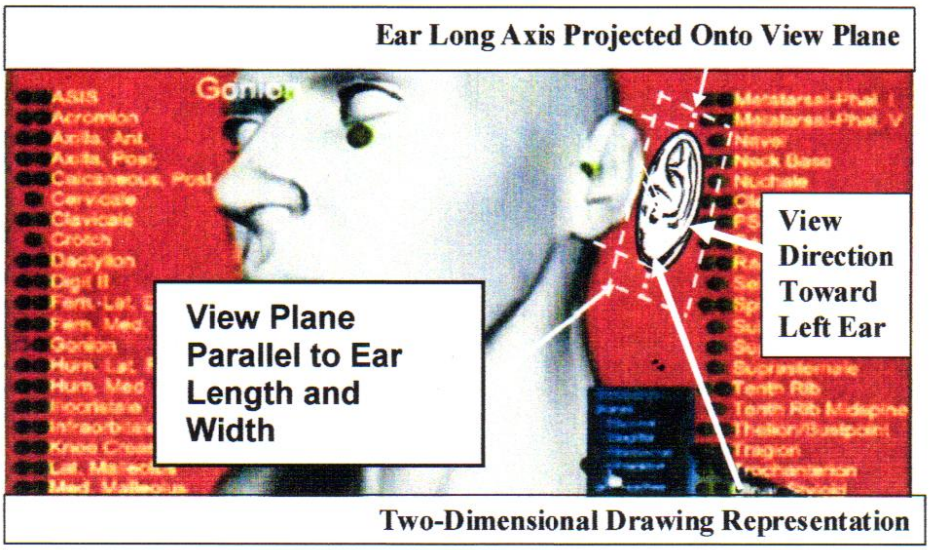

Fig. 1. Concept for Ear Primary View Plane (EP.VP)L for Left Ear
Background art by permission of S. Ressler (2001).

6.2. Section Plane concept

While the (EP.VP) concept adequately facilitates illustrating two dimensions (length and width), another closely related, complementary concept is needed to illustrate the third dimension of the complex shapes of ears. The concept recommended herein is that of cross-section views that are defined as located on planes that are perpendicular to an Ear Primary View Plane. These are herein called “Section Planes.” Their abbreviations have, besides a suitable upper case acronym, the symbols “.SP” appended.

Because many dimensions used by plastic surgeons and anthropologists are direct, point-to-point (sightline) distances, their location and (perhaps foreshortened) distance can be represented as edge views on an (EP.VP) by straight lines. Such lines can be construed as edge views of the cross section planes, and shown on drawings or CAD images.

Drawings of cross-section views on Section Planes also imply a specific, precise direction of view toward the ear (perpendicular to the Ear Primary View Plane), thus adding power to the solutions offered herein for omission of view direction in much of previous ear anthropometry literature.

Important results from employing these new view concepts include (1) ease of description of orientation (toward or away from the view plane as compared to “antero-later-inferior” or other complex angular descriptions) and (2) ease of displaying (and describing) true scaled length of many dimensions, especially those not precisely parallel to the Ear Primary View Plane. An example is shown in Table 5.

6.3. What can be shown on an Ear Primary View Plane?

Figure 2 shows two possible Ear Primary View Plane applications using the same basic ear figure published by Dr. M. Madzharov in 1989, which was based on his unpublished doctoral thesis of 1986.

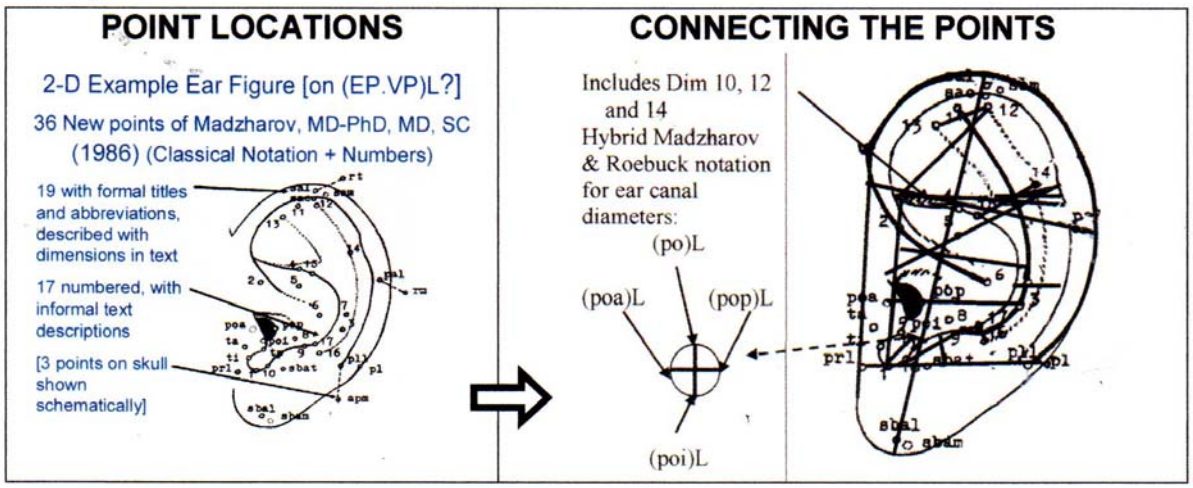

Fig. 2 Two applications for(EP.VPL using basic illustrations of ear figure
*Figure and Point Labels from Thesis of Dr. M. Madzharov, MD, PhD, MD.SC (1986)**
** Used by permission of authorized translators, I. Kamenova and V. Belenski.*

By implication, based on the majority of the point locations, most of the basic ear figures shown could be a somewhat idealized, approximate view of a left ear projected onto the conceptual Ear Primary View Plane, Left (EP.VP)L, which was illustrated in Figure 1. The left side of Figure 2 simply shows landmark point locations and labels as they appeared in the thesis. Some of the points at the upper and lower end of the ear are probably schematically located to clearly distinguish their presence. Three points located on the skull would probably be located behind the ear if shown as a strictly orthographic, auxiliary projection on an engineering drawing. At least one other view, such as a rear projection perpendicular to a Cranial Coronal (Frontal) Plane would be needed to show the true scaled length of the lateral protrusions of the noted points relative to the side of the skull.
All of the labeled points are claimed as newly invented by Dr. M. Madzharov and, taken together, amount to a remarkably large new contribution to the literature on ear anthropometry. Note that some of the points are labeled with numbers but others are labeled with acronyms for the new titles invented by Dr. M. Madzharov following the classical style of Martin and Saller (1957). They do not indicate left or right side. A few points in this figure apparently have some small errors of location which were addressed with alternative interpretation illustrations.
The right side of the figure offers another type of application for the Ear Primary View Plane concept, a summary of the majority of ear dimensions Dr. M. Madzharov, depicted as lines connecting his points to create a kind of “road map.” This figure is somewhat analogous to a ledger in business accounting, which summarizes the results of many transactions for each account. Not shown are the three projections from the skull or any “depth” dimensions (approximately perpendicular to the view plane) or angles of pitch, roll and yaw of the ear. It was found that very few of the width dimensions are directly related to the outer boundaries of the ear, and none are defined in relation to the central long axis. However, it appears that some width dimensions can be combined to provide useful estimates. Algorithms for such dimensions are being developed. Other information from different studies is needed to “fine tune” such estimates and relate them to a stable axis system such as the ear long axis or the ear baseline (obs)-(obi):

6.4. Steps in Interpretation of Madzharov Dimension Descriptions and Illustrations

Following is a brief summary of many steps of an unique process of advancement in ear anthropometry that especially constitutes a significant contributions to anthropometric accounting. The task involved an extended effort over a period of more than 7 years to date. In involved searching for and obtaining copies of extracts on ear anthropometry from a major unpublished doctoral thesis, originally typed in 1986 in Bulgarian, with Latin terms for anatomy (and a few German titles) by the plastic surgeon author, Dr. M Madzharov, MD, PhD, MD,SC, who died in April, 2013. Compared to the next largest document found in the literature to date. the thesis included more than three times the number of ear dimensions.
The second step was careful transliteration of the original text to “bring this treasure to light,” which was mostly performed by Irena Kamenova, a librarian residing in Colorado, who is fluent in Bulgarian and English. Some additional smoothing and interpretation into technical English was done by J. A.

Roebuck, Jr. Scanning of the photocopies of the original text into computer-readable format and reviews of technical aspects of some translations was done by Viktor Belenski, husband of Ms. Kamenova.
In the third step, Roebuck developed alternative interpretations of the titles, abbreviations and illustrations to more closely conform to modern engineering anthropometry word order, to create simpler titles and to enhance illustrations with engineering drafting conventions to be more suitable for use in developing digital models of human ears (Roebuck, Madzharov, Kamenova, and Belenski, 2013): In many cases, 3-D concepts were illustrated by use of cross-section drawings.
In the fourth step, 31 points identified in the thesis only by numbers and informal, brief descriptions were given newly invented formal titles and abbreviations to make them more consistent and "portable" to new documents. Appropriate corrections were made to deal with discrepancies between text and illustrations. In this work, significant help was available from technical articles published in English by Dr. M. Madzharov. The translation for all of the dimension descriptions has been completed in draft form, but much work remains to deal with the tables and graphs of ear anthropometric data and descriptions of the survey activities that produced them. Material from the thesis extracts has been included in several draft documents (Roebuck, 2011a, 2911b, 2011c and 2011d) and as examples in this article, to highlight both the unique values and the associated remaining problems in anthropometric accounting.

7. Discussion: Solving problems of 2-D thinking about 3-D objects

One of the unfortunate hard realities found in much of the anthropometric literature is the tendency of authors to describe geometric features of their ear figures and associated dimensions as if they only exist on a two-dimensional plane rather than in three-dimensional space. The problem is most prevalent in the literature of ear anthropometry because of the complex, highly variable shapes and great variability of ear orientation angles. Apparently, many anthropologists and plastic surgeons are not trained in the skills of engineering drafting and descriptive geometry which might alert them to such problems as lines (representing dimension distances) that do not actually coincide in three-dimensional space, and therefore cannot, strictly speaking, be claimed as perpendicular to each other. Similarly, some lines said to "cross" or "intersect" may actually pass by an ear feature like a bridge over a river, and never meet.
The new concept of "Section Planes" described above can help solve these problems for describing three-dimensional shapes of ears, but the text descriptions and drawing labels should be altered to clearly indicate these alternative interpretations. Such alterations may include changing "lines" to "planes" and providing new titles and abbreviation symbols to distinguish between plane figure concepts ant three-dimensional shape concepts.
Other, more subtle errors of 2-D thinking in relation to point location include points thought to be "highest" as determined in relation to the direction of gravity instead of in relation to the ear long axis orientation as originally shown in figures of Martin (1914): Similar errors of interpretation of early publications appear for horizontal distances from the face instead of distance perpendicular to the ear long axis as originally shown in figures of Martin (1914):

7.1. New Notation for accommodating to 2-D descriptions found in the ear anthropometry literature

An option for dealing with ear anthropometry descriptions that focus on 2-concepts is to accept the authors viewpoint, but clearly identify it by revising the titles and abbreviations for the points and lines in question to identify them as "images" on a two-dimensional plane. In fact, the word "Image" should be included in the titles. Then, it is herein recommended that the point abbreviations be modified to add the suffix ".i" within the parentheses. Similarly, the abbreviations for lines or surface path constraints can be modified by adding the upper case symbol ".I" (within the parentheses for lines and planes. The latter change is not appropriate for path constraint codes (C1 through C6), which have no enclosing parentheses or brackets*. In using this approach, one can consider the designated view plane (e.g., usually (EP.VP) as "opaque," like a hard copy drawing glued onto the view plane in space. In contrast, when the descriptive text and other information obviously are dealing with 3-D concepts, the view plane can be considered as a transparent "window" through which one can see the features, points and lines at appropriate distances from the view plane. On the latter illustrations, the ".i" and ".I" are not needed.

7.2. Examples of alternative interpretations of titles, abbreviations and illustrations for straight and curved dimensions

Tables 5, 6 and 7 present alternative interpretations of two dimensions that appeared in the thesis of Dr. M. Madzharov. Tables 5 and 6 have a similar content of columns for alternative text and its original form in the thesis. Table 5 shows a straight line, "depth " (distance into a cavity, approximately perpendicular to "length" and "width."), and thus not readily shown as lines on the (EP.VP) auxiliary plane. In Column 5 is shown an example of the use of a Section Plane concept (Section A – A, which is perpendicular to (EP.VP)L shown in Column 6) on which the dimension can be shown in true length. However, in this case the dimension is a "projected" type (Code C2) rather than a point-to-point (sightline) type (which would be coded C3 in the recommended notation system). Therefore, the illustrations show how such projected distances can be displayed, using standard engineering drafting practice with an Extension Line and arrows.

In both Tables 5 and 6, Columns 1 through 4 refer to 3-D concepts for location and shape of delimitations, but there are differences between these tables as regards columns 5 and 6.. In each, Column 1 includes a number for the dimension and the page where it appears in the thesis of Dr. M. Madzharov (1986). Similarly, Column 2 includes alternative dimension titles in a new format (indicating left and right side), based on modern engineering technical English word order for anthropometric dimensions (exemplified in Gordon et al., 1989): It also shows the initial transliteration into English and the original Bulgarian (in Cyrillic font) and Latin words below the word "Was."

In both Tables 5 and 6, Column 3 shows the recommended abbreviation symbols for two end conditions. Between the end conditions are codes for intermediate path information. In Table 5, an abbreviation for an extension line is shown: ((AAT.EL)L for the left side. However, for Table 6, there are lower case letter codes (b, c, d, and e) (which are explained in Table 7), denoting intermediate landmark points along the curved path,. These help to describe the curved path for the dimension. The path shape is further confirmed by a code for the path constraint, "C5B", which means a "non-planar, open curved path" and another acronym code (which is optional) offering a specific acronym for a title of a line along the curved distance, "(HMS.CL)" (for Helix Margin Surface Curved Line). Column 3 also highlights a "Related Line Abbreviation," which is listed at the bottom in both tables 5 and 6.

In both Tables 5 and 6, the formal text titles for each delimitation are shown in Column 4, including titles for associated lines and planes shown at the bottom of the column.. Column 5 is different for the two tables: A cross section is shown in Table 5, but only comments are included in Table 6.

Column 6 in both Tables 5 and 6 is where an Ear Primary View Plane is used to show the location and orientation of the dimension of concern. The plane is "transparent" in Table 5, which features a cutting plane for a cross-section, but is "opaque" (2-D) in Table 6, so a ".i" suffix is included for each point label.

Table 7 is a sample format for supplementing information on dimensions with multiple points along a curved line, in this case specifically for the curved helix length described in Table 6, It displays columns showing recommended titles and abbreviations for each point in sequence from one end of a dimension to the other, primarily for intermediate points between the two end conditions. However the sample also shows columns for the end conditions. The latter are shown in *italics* in the specific sample, and considered optional for such a table format. The column on the right (for Alternative Point f) reflects uncertainty about the meaning of (pll) as described in the thesis of Dr. M. Madzharov. The specific curved helix path shown in Table 6 is identified as Option 1A in the left column of Table 7. This option is one of several possibilities that have been inferred from the thesis descriptions for the helix shape. For each such option, separate tables like Tables 6 and 7 are needed. For simplicity, only the 3-D concepts (not the "Image" points with suffix ".i") are shown in the column headings of Table 7. Note that similar information, as found in several different references, could be included in such tables by adding rows.

Together, Tables 6 and 7 exemplify a new way to display useful information for multiple Intermediate points on illustrations along a dimension path, whether curved or straight,, to minimize visual clutter.

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* A detailed description of each of these path constraint codes will be included in a guidelines document (Roebuck, 2011b):

Table 5. A Sample Tabular Presentation of Alternative Interpretations of Titles, Abbreviations and Illustrations for Straight Line Depth Dimensions as Found in the 1986 Thesis of M. Madzharov MD, PhD, MD.SC.*
** Basic ear figure in Column 6 used by permission of authorized translators, I. Kamenova and V. Belenski ©*

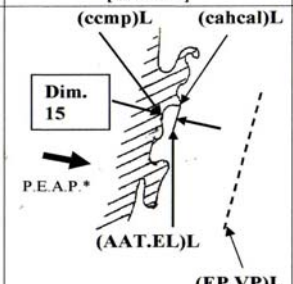
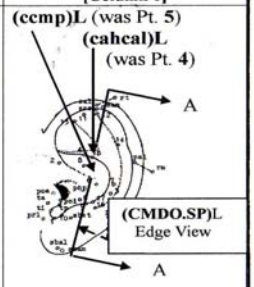
Dimens. and Page No's [Col. 1]	Alternative English Titles (3-D) [Column 2]	Delimitation Abbreviations (3-D) [Column 3]	Delimitation Titles (3-D) [Column 4]	Cross-Section Depicting true length, location & angle of dimension [Column 5]	3-D Projection To Ear Primary View Plane (EP.VP)L [Column 6]
15., P. 64 (A projected dimension)	Cymba Conchae Depth, Left	(cahcal)L-(AAT.EL)L-(ccmp)L, C2,	Crus Anthelicocristale Anterolaterale, Left – Anthelix AnteriorTangent Extension Line, Left-- Cymba Conchae Medioprofundus, Left, Projected Normal to (EP.VP)L	 **Section A-A In (CMDO.SP)L** (Direction of view; distally, perpendicular to **(CMDO.SP)L**) **Lefts side shown, right side opposite.** *** = Primaria Erga Auriculo Planum (Toward the Primary Ear Plane)**	 **Fig. 2-9 Ear Illustration from Madzharov Thesis With Modifications** View Direction Normal to (EP.VP)L **Lefts side shown, right side opposite.**
	Cymba Conchae Depth, Right Was: Depth of *cymba conchae.* = "Дълбочина на *cymba conchae.* Rationale for Alternatives: Deletes "of,"	(cahcal)R-(AAT.EL)R-(ccmp)R, C2, Was: (Fig. 2-9, Pt. 4) – (Fig. 2-9, Pt. 5) Related Plane Abbreviations: (CMDO.SP)L and R Related Line Abbreviations (AAT.EL)L and R…	Crus Anthelicocristale Anterolaterale, Left, Right Anthelix AnteriorTangent Extension Line, Right-- Cymba Conchae Medioprofundus, Right, Projected Normal to (EP.VP)R Was: (No formal titles assigned in thesis) Related Plane Titles: - Cymba Maximum Depth Overlook Section Plane, Left and Right Related Line Titles: Anthelix Anterior Tangent Extension Line, Left and Right		

Table 6. A Sample Tabular Presentation of Alternative Interpretations of Titles, Abbreviations and Illustrations for Curved Line Dimensions as Found in the Thesis of Dr. M. Madzharov (1986).*
Basic ear figure in Column 6 used by permission of authorized translators, I. Kamenova and V. Belenski.

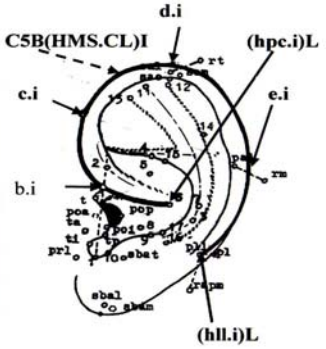
Dimens. and Page Nos. [Col. 1]	Alternative English Titles (3-D) [Column 2]	Delimitation Abbreviations (3-D) [Column 3]	Delimitation Titles (3-D) [Column4]	Comments [Column 5]	2-D Illustration Using Ear Primary View Plane (EP.VP)L, Image Abbreviations (".i," "I") (5,6) [Column 6]
34., P. 68 See also: **35**, P.68, **36.**, P. 68	Helix Path Length, Left Helix Path Length, Right Was: Physiognomic length of *helix* = "Физиономична дължина на helix." Rationale for Alternatives: Ddeleted "physiognomic" and "of." Emphasized curved path shape (not chord or diameter).	(hpc)L-b-c-d-e**-(hll)L C5B(HMS.CL) (hpc)R-b-c-d-e**(hll)R C5B(HMS.CL) (** = See Table. below for meaning of single letter codes) Was: (Fig. 2-9, Pt. 6)-(*pll*) Rationale for Alternatives: Changed abbreviation (*pll*) to (hll) to emphasize horizontal and vertical location at juncture of helix and earlobe. Related Line Abbreviations: (HMS.CL)……	Helicoprincipio Conchale, Left –b-c-d-e**- Helicolobulare Laterale, Left, Non-Planar, Open Curved Path, Helix Margin Surface Curved Line Helicoprincipio Conchale, Right-b-c-d-e**-Helicolobulare Laterale, Right, Non-Planar, Open Curved Path, Helix Margin Surface Curved Line ** = See Table below. Rationale for Alternatives: "Helicolobulare Laterale" defines location at juncture of helix and earlobe and avoids term "post-," which implies distance measured posteriorly from front to back.. Related Line Titles: Helix Margin Surface Curved Line (Left and right implied)	Curved dimension starts from crest line at principal point in concha, follows lower, margin (edge) of helix crus anteriorly and upward to *otobasion superius*, thence around margin (outermost edge) of helix and downward until it transitions into ear lobe at most laterally protruded point on skin surface. A Section Plane is not appropriate to show the path for this complex curved dimension.	 **Fig. 2-9 Ear Illustration Modified from Madzharov Thesis** **View Direction Normal to (EP.VP)L (7)** **Left Side Shown, Right Side Opposite** (See Table below for meaning of intermediate letter codes along path of dimension)

Table 7. A sample of new tabular approach for identifying points along a curved dimension.

Path Option, Author	*Point a Abbr. Title*	Point b Abbrev. Title	Point c Abbrev. Title	Point d Abbrev. Title	Point e Abbrev.. Title	*Point f Abbrev. Title*	*Alternative Pt. f Abbr. Title*
1A. **Roebuck**	*(hpc)L, (hpc)R* ---------- *Helico-principio Conchale, Left and Right*	(sbhcm)L, (sbhcm)R ---------- Subhelico-crusale Medius, Left and Right	(obs)L (obs)R ---------- Otobasion Superius, Left and Right	(sa)L, (sa))R ---------- Super-aurale, Left and Right	(hpd)L, (hpd)R ---------- Helico-prominen-sion Distale, Left and Right	*(hll)L (hll)R* ---------- *Helico-lobulare Laterale, Left and Right)*	*(hld)L, (hld)R* ---------- *Helico-lobulare Distale, Left and Right*
1A. **Madzharov**	*(Fig. 2-9, Pt. 6) (Briefly described in the thesis)*	None listed in thesis	(*obs*) ---------- o*tobasion superius*	*(sa*) ---------- *superaurale* [Unlisted, but possible assumption]	(*pa*) ---------- *postaurale* [Unlisted, but possible assumption]	*(pll)* ---------- *post-lobulare laterale*	*(pl)* ---------- *postlobulare [Assumes possible error in descriptive text]*

8. Conclusions and summary

The advances described in the foregoing presentations offer new methods for reducing errors and confusion found in many previously published documents in the anthropometric literature. The proposed advances have laid ground work for using the numerical thesis data of Dr. M. Madzharov(1986) and many others for developing algorithms for digital human modeling of ears. Admittedly, complete implementation of the accounting system will not be easy for future anthropometry, because the system requires much detailed work to find and enter the recommended abbreviation symbols for end conditions, intermediate points (in some cases) and path constraint codes (except for standard dimensions oriented perpendicular to anthropometric Principal Planes) . Such work may be dependent on completion of several new documents now draft form (Roebuck, 2004), (Roebuck, 2011a), (Roebuck, 2011b), (Roebuck, 2011c) (Roebuck, 2011d) (Roebuck, Madzharov, Kamenova and Belenski, 2013): Assistance for completing and publishing these documents would be welcomed by the author.

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