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An Innovative Decision Making e-key Application For the Identification of Fish Species

George Minos, Vassilis Kostoglou, and Emmanouil Tolis

Abstract The most important tool for ichthyologists, as well as biologists, fishery biologists and other relevant scientists is an identification key, that is an information system providing them the capability to identify specimens accurately or to find information on correct names, biology and distribution of species. Dichotomous identification keys organize fishes based on their similarities and differences. This research work focuses on the development and implementation of a new innovative information system which is able to identify correctly fish species. The developed system is a fully interactive fish identification e-key which can be used in both forms; locally and remotely via Internet, and more specifically the Telnet service. This new dichotomous classification e-key provides the capability to identify any species in a compact and easy-to-use environment which gives the user excellent operation capabilities and complete information about all included fish species. Moreover, the application provides the capability to search for a sporadic fish species and to show a list which includes all the fish species that exist to the application's database until that time.

Key words Information system • Decision-making application • Identification key • E-key • Fish • Species

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1 Introduction

There are about 28,000 living species of fishes which makes very difficult their correct classification [9]. The identification of the various fish species is based on morphometric characters (measurable structures such as fin length, head length, etc.), meristic characters (countable structures such as number of scales in the lateral line, number of vertebrae, etc.), anatomical characters of the skeleton and the soft anatomy or characters that include any fixed, describable differences among taxa such as color (presence of stripes, spots) photophores (number and position) and sexually dimorphic structures [1, 9].

To classify different species a dichotomous identification key is used, which is an extremely important tool in science. The primary aims of an identification key are to enable species to be identified correctly and to summarize what is known on their biology and geographical distribution. In order to identify a fish with the use of a dichotomous key, the user works through a series of questions and illustrations which eventually lead him to the species matching best the characteristics he has set.

Systematics (or taxonomy) is the biological science responsible for the classification of living organisms in a hierarchically organized system representing the evolutionary kinship of the various systematic groups. In classification, the use of morphological, anatomical, physiological and other characteristics is made to decide the existing relationships [1]. The basic systematic unit (taxon) is the species followed (in ascending order) by the genus, family, order, class, superclass, subphylum and the phylum.

Like other animals and plants, fishes are known by common names and scientific names. While common names differ from country to country, scientific names are universal. Aristotle was the first to classify the animals known in his days, but the first generally acknowledged scientific classification of animals and plants was by Carl Linnaeus who introduced the binomial system, in which every species was given two Latin or Greek names. Since the scientific name consists of two parts, the first italicized word, with the initial letter capitalized, is the genus while the second italicized word is the specific (species) name.

The existing identification keys are divided into two categories: (1) printed keys and (2) electronic keys (e-keys). The former are printed in the form of a book and they mostly still keep this form so far. Nevertheless, e-keys have been developed in recent years. Examples of printed identification keys are books dealing with fishes from the Mediterranean Sea [7, 13], Atlantic Ocean [2, 6, 12], Indian and Pacific Ocean [3–5] and Greek seas [10]. The main disadvantage of the printed identification keys is that it is easy to make a few wrong decisions when navigating through the test. So, when someone is deadlocked or makes a wrong selection, it is not easy to go to a previous selection (family, suborder, etc.) because there is not an area that shows the history of the selections. In a case like this, the reader has to find the previous selections that he made and the page in which they were. Furthermore, when the selections are too many, it leads to confusion for the reader. Also, it must

be mentioned the case where new dichotomous keys must be created and printed which will be used to identify new organisms (fish species) that will appear in the area in the future.

For this reason, fish identification keys evolved as e-keys. There are many examples of fish identification e-keys because, as technology boomed, several keys of this type were developed to facilitate ichthyologists, students or persons who needed such tools. All fish identification e-keys are based on printed keys (books). No new keys have been created, but the book contents have been digitized. Some examples of identification keys in World Wide Web are in *FishBase* [8] per Food and Agriculture Organization (FAO) area, per order or per family or quick identification by image and also identification by morphometrics. An important tool is the *Marine Species Identification Portal* (http://species-identification.org) while the *Fish Identification Site* (http://svrsh2.kahaku.go.jp/fishis) helps to identify fishes utilizing countable characters such as numbers of fin rays, scales, pores, gill rakers, body rings and vertebrae. Other identification e-keys are for specific state in the USA (www.theanglingchannel.com/fish-identification-encyclopedia-resources.html) like the *Identification Key to Native Freshwater Fishes of Peninsular Florida* (www.flmnh.ufl.edu/fish/southflorida/everglades/marshes/fishkeyedu.html). The common feature of these keys is that they are web applications. This means that they are uploaded as webpages into a web site and when someone wants to use them, he just has to visit the specific website.

There are few mobile applications for iPad, iPod and iPhone (http://itunes.apple.com/us/genre/ios/id36?mt=8) to identify fish species. The *Marine Fishes - Identification Guide* is based on the book entitled *Marine Fishes of Brazil - A Practical Identification Guide* and is limited on a specific number (200) of marine fish species from Brazil. In the application *Fish*, the number of fishes is very limited, since it is a Fish Guide reporting only a part of the common fish swimming in streams, lakes and rivers across the North Woods, US. In the application *FishID - Know every fish, fish every spot and spot the best catch*, appear only eight saltwater fishes. There are also other mobile fish-related applications for iPhone and iPad that are not identification keys. The *Sharks Magazine* contains information on sharks, *MarineLife - Genus trait Handbook* on marine life species, *Fish Alkhaleej* on common fish in Arabian countries, *Fish Complete Reference* and *Fishes of the World - eFishesW* information on fish species and *Marine Fish Encyclopedia* on common marine aquarium fish.

The available Android applications (https://market.android.com/) are fewer in number than the iTunes ones. None of them gives the ability for the species identification. Some give the description and illustrations for the most common fishes (e.g. *North American Fish Guide, FL SW Fishing Regulations, Saltwater Pocket Fisherman, The Pocket Fisherman-Freshwater edition*). Other Android applications are useful only for fishing on where and how to catch fish, such as *My Fishing Advisor, Fishing Status, Tide Prediction, Fishing Calendar* and *Fish Cast 2012*.

A dichotomous key is a tool that allows the user to determine the identity (specific name) of a fish. These keys consist of a series of "either or" choices that lead the user to the correct name. "Dichotomous" means "divided into two parts". Therefore, dichotomous keys always give two choices in each step.

Technically, there are two types of e-keys. The more simple e-keys (with static content) are developed with HyperText Markup Language (HTML) and contain a set of information which is stored and divided into a number of pages. These pages compose a webpage. The above set of information is about key's selections, data on fish species, fish images and all the necessary information which compose a fish identification key. A simple e-key is not flexible because it does not provide updating capabilities (with which the user can add new fish species). Furthermore, a simple key lacks proper organization because it does not contain any database which can provide organized information storage. The more complex e-keys are developed under both HTML and a scripting language. The scripting language is usually either PHP (Hypertext Pre Processor) or ASP (Active Server Pages). By using a scripting language the developer is able to create a webpage with dynamic content, ensuring also that all the necessary for the operation of the e-key information is being stored into a database. This e-key does not simply show to the user a set of information which is divided into a number of webpages, but every time the user makes a selection, a set of information is being recovered from the database to be shown to the browser. As e-keys of this type are using databases, they could provide updating capabilities. An extensive literature review of the existing fish identification e-keys revealed that there are no e-keys providing complete and correct update capability.

The information system that has been designed and developed in the present work constitutes the first fish identification e-key for all the Mediterranean fish species of the Greek seas. The designed system is fully interactive with the user and can be used in both forms; locally and remotely via the World Wide Web. As the information system constitutes a desktop application, it provides an easy and user-friendly environment which gives the user multifaceted fish identification capabilities and an effective search function for all included fish species. Furthermore, its navigation function is a strong and useful advantage. Finally, its additional function which shows information about the fish systematic taxonomy is innovative.

2 Methodology

The information system has been developed with the Java object-oriented programming language. The system was necessary to have a database to connect to, so that to recover from this all necessary data and also to present this data as information to the end user. The database includes full information about every level of the fish systematic taxonomy, as well as images of every one of the 511 existing fish species. The *Relational Database Management System* (RDBMS) that was used to manage the database of the information system is MySQL. It was selected in order to provide to the information system the capability to connect to a single database, common to all users as it is uploaded to a Web Server. The above feature is usual for MySQL and it does not exist in all other RDBMSs, either they are free or not. MySQL can also be used locally at the personal computer of a user. In this case, each user's personal computer takes Web Server's role. So, each personal computer keeps the database

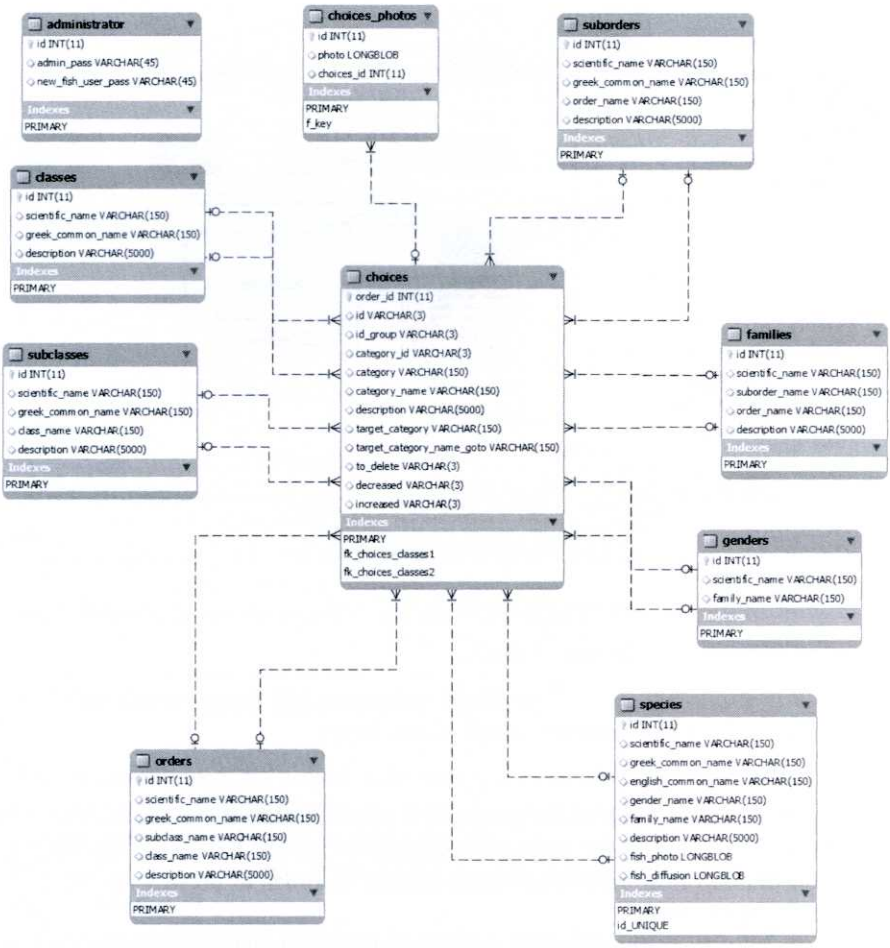

Fig. 1 Information system's database structure through an ER diagram

stored in it. Regarding the fish information included in the new information system, all data and images of the main relevant published identification keys [10, 11] were digitized and transferred.

Figure 1 presents the structure of the database through an Entity-Relationship (ER) diagram. The diagram includes the main table containing information about all possible selections of the user, as well as all the other tables with the corresponding information. These tables have direct link with the main table, as every level of the fish systematic taxonomy hierarchy participates in the fish identification key selections.

A relevant class diagram is illustrated in Fig. 2. This diagram belongs to the object-oriented programming diagrams and generally reflects the structure of a system. It contains all the existing system units, called classes, and the connections

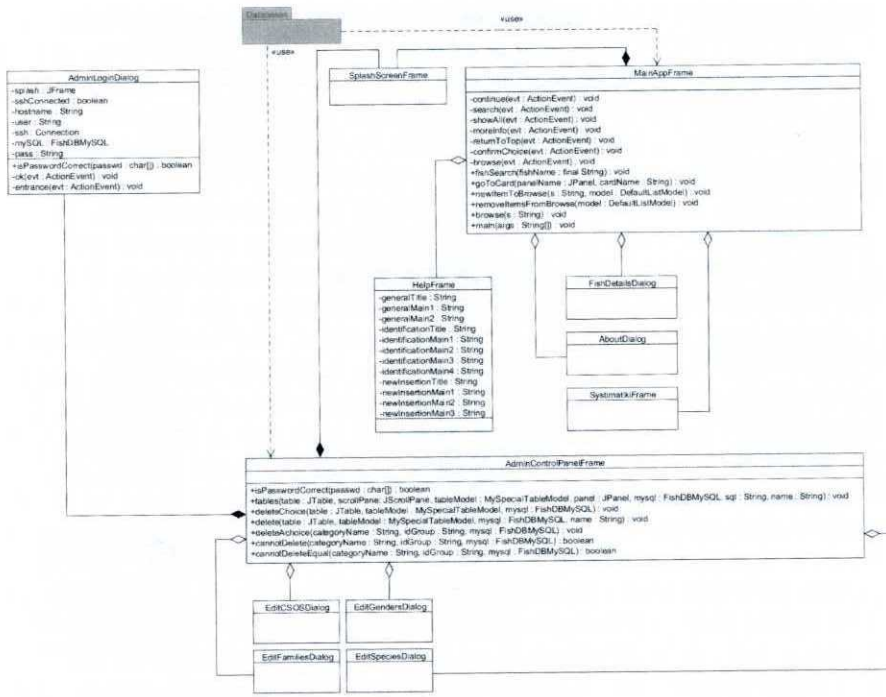

Fig. 2 Information system's structure through a class diagram

among them. These connections present the existing relations of dependence and use among the classes. The main properties and methods have been included in the presentation of the most significant classes, in order to present the elements composing such a unit.

Figure 3 illustrates the overall flow control of the information system through an *activity diagram*, presenting the software process as a flow of work through a series of actions. The diagram represents graphically the workflows of stepwise activities and actions with support for choice, iteration and concurrency. The activity diagram depicts all the main application's processes and the choices the user can make while using the information system. More specifically, it depicts all the activities (rounded rectangles), the control flows between them (arrows), the decision and merge nodes (diamonds), the object node (rectangle), the initial node (filled circle) and the activity final node (filled circle with border).

Two programming tools have been used for the development of the information system: Netbeans IDE 6.9.1 for the programming part, and MySQL Workbench 5.2.31 CE for database design and management. Apart from the above basic tools, a Java library was also used. This library is the Ganymed SSH-2 for Java library and was used in order to support the development of the information system. This library implements the SSH-2 network protocol and gives to a Java program the capability to connect with an SSH Server.

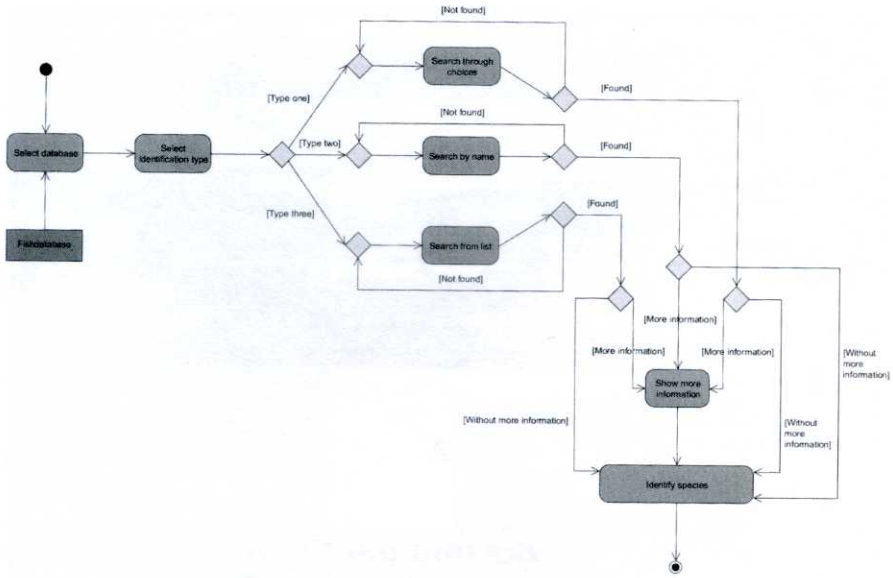

Fig. 3 Information system's overall flow of control through an activity diagram

3 The Developed Information System

The information system provides the user the capability to identify a fish species by making some selections relevant to species' external morphology. When starting the application the user has to choose one of the two databases (local or online) and type a password. After that, the main menu of the e-key appears at the upper part of the screen (Fig. 4).

The screen is divided into three horizontal parts. The upper part and the bottom part are static. Conversely, the central part is dynamic. In the upper part of the screen there are application's two main functions: (1) the *Show all species* function and (2) the *Search species* function. The bottom part constitutes a status bar which contains information about the connected database and a bar which informs the user about the progress of a specific search procedure.

The central part of the e-key (Fig. 4) consists of the following sections: (1) the table at the center which contains the texts of the current dichotomous selection and two relevant actions, to confirm the selection or to return to the beginning, (2) the area below the table which shows more information to help user's selection, (3) the navigation at the left side and (4) the area at the right side which shows more information about the current level in which user is based on his selections. The upper section of the center part (above the table) contains a title which informs the user about the application's function that is being executed at that time.

If the user intends to use the fish identification function, he has to select one of the two selections in the central part (area 1) and press the button *Confirm your table*

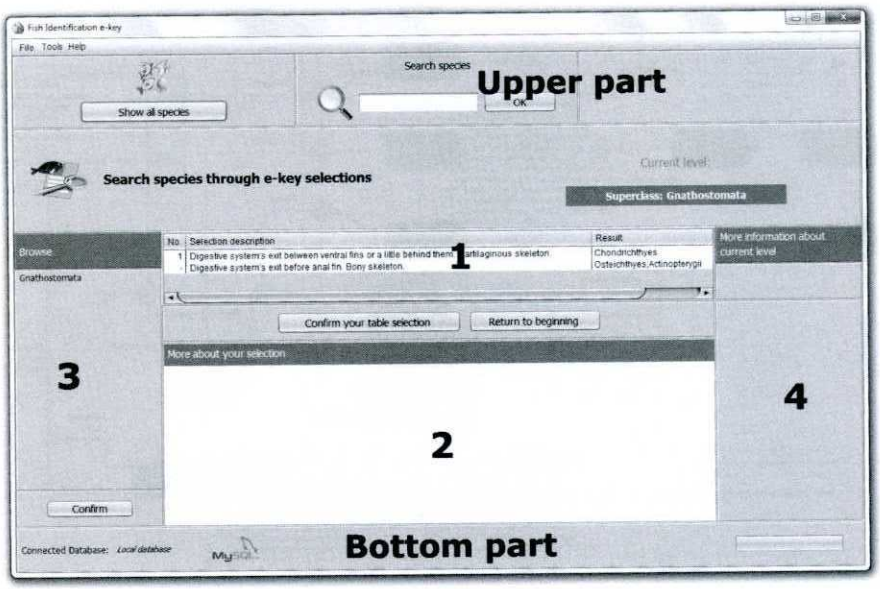

Fig. 4 Main screen of the fish identification e-key

selection. Anytime he wants to return to the selections in the start of the key, he can just press the button *Return to beginning*. Every time the user makes a selection, he can read its full description (area 2). Also, when it is necessary, this area shows an image which describes optically user's selection. Furthermore, every user's selection is being recorded in the navigation list (area 3), so that he can anytime go back to a previous step. This list is very useful, as it presents the whole route till the final successful fish identification.

The left selection of the upper part (area 1—*Show all species*) leads to a table including all the fish species that are stored at the selected database until that time. This area also contains two selections (*More information about the species* and *Back to e-key*). The former requires the selection of a row from the fishes' table and presents all the stored information about the selected species including names, picture, description and geographical distribution (Fig. 5). The latter restores the fish identification screen at the central part of the screen.

4 The User Interface

The information system's user interface has been designed with the aim to be simple and friendly in its use. It has been designed to correspond fully to the needs of an ichthyologist without significant experience in the use of computers.

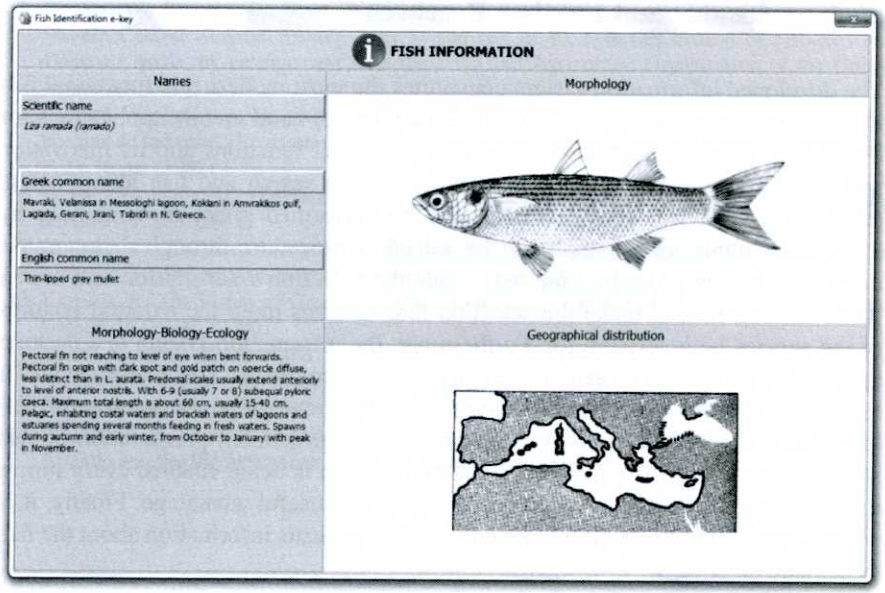

Fig. 5 Fish identification - Window with species information

In the design phase of the system, emphasis has been given to the segregation of the main screen into distinguished parts enabling the user to see all the information he needs in a well legible way. Additionally, the use of titled buttons corresponding to the various operations enables the user to perform them immediately and very easily.

In the user's interface section, concerning the main operation of the identification of a fish species, the main window has been separated in four horizontal parts (Fig. 2). The first part contains the three main operations (show, search and insertion) in order to be continuously available to the user. The second part informs the user about the current operation, as well as for relevant useful information. The third horizontal part changes according to the selected operation, presenting to the user either his search results or his selections for the specification of a certain species. The last part is the system's status bar informing the user about technical issues of the application. All the operations are supported by corresponding buttons and full navigation capabilities.

The developed information system has been tested extensively through successive pilot trials with 10 users. Users' feedback was satisfactory as the information system covered their needs. It is worth noting that most users appreciated the navigation operation and noted that it has been proved very useful and easy to use.

5 Conclusions and Further Research

The developed information system constitutes the most modern and functional fish identification e-key, compared with the existing e-keys and mobile applications for iPad, iPod, iPhone and Android. Both its additional functions and its innovation make it special. It provides the user with multiple search and fish identification capabilities. The fish species search can be performed either by searching by the species name, or by applying the selection procedure through dichotomous questions. In this procedure the user reads the selection's description and sees a photo, so that he can make the selection that matches more the external features of the species he is looking for. Furthermore, the information system is a desktop application which can be installed on any personal computer. This feature makes it functionally faster than other respective web applications. Also, its search capability gives very fast results, as well as an organized and detailed presentation of fish species information. The navigation function, which is being enabled every time a user is trying to identify a species, is a strong and useful advantage. Finally, it is worth mentioning the additional function which presents information about the fish systematic taxonomy.

Some proposed issues for further relevant research are the following: (1) Conversion of the information system to a mobile application for use by mobile phones, smart phones or tablets with touchscreen utilizing popular operating systems, such as iOS (iPhone, iPad), Android or Windows Phone, (2) Application's extension to a wider geographical area (Mediterranean Sea, Atlantic Ocean, etc.) and/or to a specific fish fauna (e.g. fishes in fresh waters), and (3) the most innovative new feature would be the addition of updating capabilities which will allow users to add to the existing database new fish species. Current research of the authors of the present article focuses on the requirement analysis and implementation of this specific issue.

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Optimization Theory, Decision Making, and Operations Research Applications

Proceedings of the 1st International Symposium and 10th Balkan Conference on Operational Research

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