ColectoR, a Digital Field Notebook for Voucher Specimen Collection for Smartphones

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SOFTWARE NOTE

COLECTOR, A DIGITAL FIELD NOTEBOOK FOR VOUCHER SPECIMEN COLLECTION FOR SMARTPHONES[1]

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- *Premise of the study:* ColectoR was developed to aid botanists in the collection of data for voucher specimens using smartphones, accelerating the process of data capture in situ and its subsequent organization.
- *Methods and Results:* ColectoR features a minimalist design that uses an intuitive iconic interface. The integration of external application programming interfaces (APIs) and an automated spreadsheet extends its functionality and increases the information and tools available to the user. This app is currently supported by any Android device.
- *Conclusions:* ColectoR provides an efficient method for capturing data in the field while also serving to organize the information into a coherent database, thereby greatly reducing the time required for postcapture data organization and label printing.

Key words: botany app; database; fieldwork; herbarium labels; plant collection; smartphone app.

Despite being poorly documented in the literature, it is well-known, at least anecdotally, that collecting plant specimens in the field requires considerable postfieldwork data organization and processing. Collection information must be organized in a database and/or printed on identification labels for herbarium specimens. This process is usually a very time-consuming task (Fish, 1999) that sometimes requires more time than collecting the plants themselves, especially using traditional data-capture methodologies. Because fieldwork is often expensive and requires considerable planning and attention to logistical details, it is desirable to spend time in the field collecting plants, and less time organizing and processing field collections. The goal of this effort was to develop a method that allows data capture in the field to be quick and efficient, with the data organized in a way that considerably reduces the amount of time devoted to postfieldwork data processing.

In the field, a typical botanist devotes approximately five minutes to data capture for a single collection. In a previous attempt to reduce the time required for organizing and processing field data, the use of automated spreadsheets and portable devices like personal digital assistants or lightweight laptops was suggested (Germán, 1986). However, these devices decreased mobility and required a field assistant to aid in fast data entry. For this reason, I developed a nonrestrictive tool using smartphones that permits quick and efficient data entry as well as increased organization. Smartphone popularity is at an all time high, with an estimated 55.7–62% of the global population owning a smartphone (Barnard, 2015; Consumer Barometer with Google, 2016),

with nearly 82% of these being based on the Android operating system (Rivera and van der Meulen, 2015). These smartphones can include tools like global positioning systems (GPS) and altimeters and have a wide area of coverage that continues to increase daily across the world. Some companies have even developed high-end GPS with a core functional Android device, allowing for high-sensitivity antennas and the possibility of installing hundreds of applications. The ColectoR app was therefore created as a software that has the capacity to process data, organize it into a coherent database, and speed up the data-capturing process with fast entry using integrated sensors available in current smartphones. Compared to the common method of capturing the information in a physical field notebook (Fig. 1A), this app can streamline the process of precapture and postcapture data organization (Fig. 1B).

METHODS AND RESULTS

General design—ColectoR was created using the development platform MIT App Inventor 2 (Pokress and Dominguez, 2013) using native objects of the Android operating system that allow the integration of functions such as spell check, word suggestion, and voice recognition. All the elements of ColectoR increase the speed of data entry, and for that reason I designed the following aids: lists of elements that are auto-populated with each saved record, buttons that automate data collection and capture, spell checker for species, and data export functions. The graphical interface is primarily trichromatic (white, black, and yellow), where the backgrounds are white and the elements are black for easy reading in direct sunlight, even on devices that do not have ambient light sensors or automatic brightness control. All information suggested by ColectoR and requiring verification by the user appears in yellow. ColectoR includes five different screens with which the user can interact. Each screen refers to a state of the application and, therefore, to a set of specific functions for each activity. The main screen, which permits the creation of a new collection, also provides access to the configuration, export, and verification screens. The configuration screen gives access to basic configurations; in this screen it is possible to enable or disable the cellular network connection to avoid data consumption on the phone, and the user can also delete the entire database. The export screen contains everything related to the export of the database using the native Android sharing feature; these options will vary depending on the applications that each user has installed on the smartphone. If cloud storage applications like Dropbox, Google
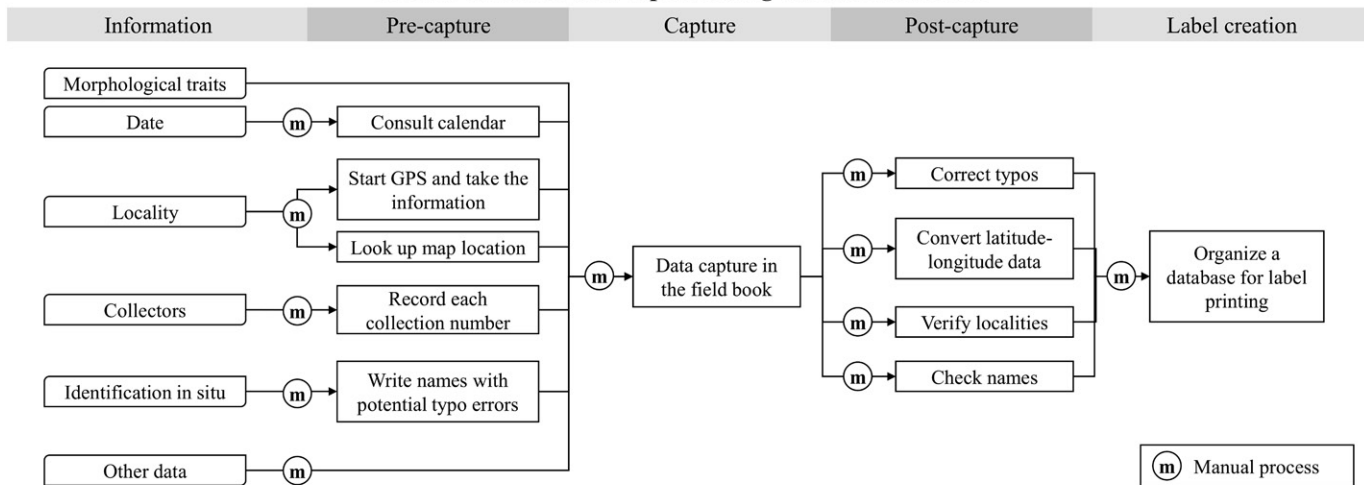
A **Flow chart for data capture using traditional method**

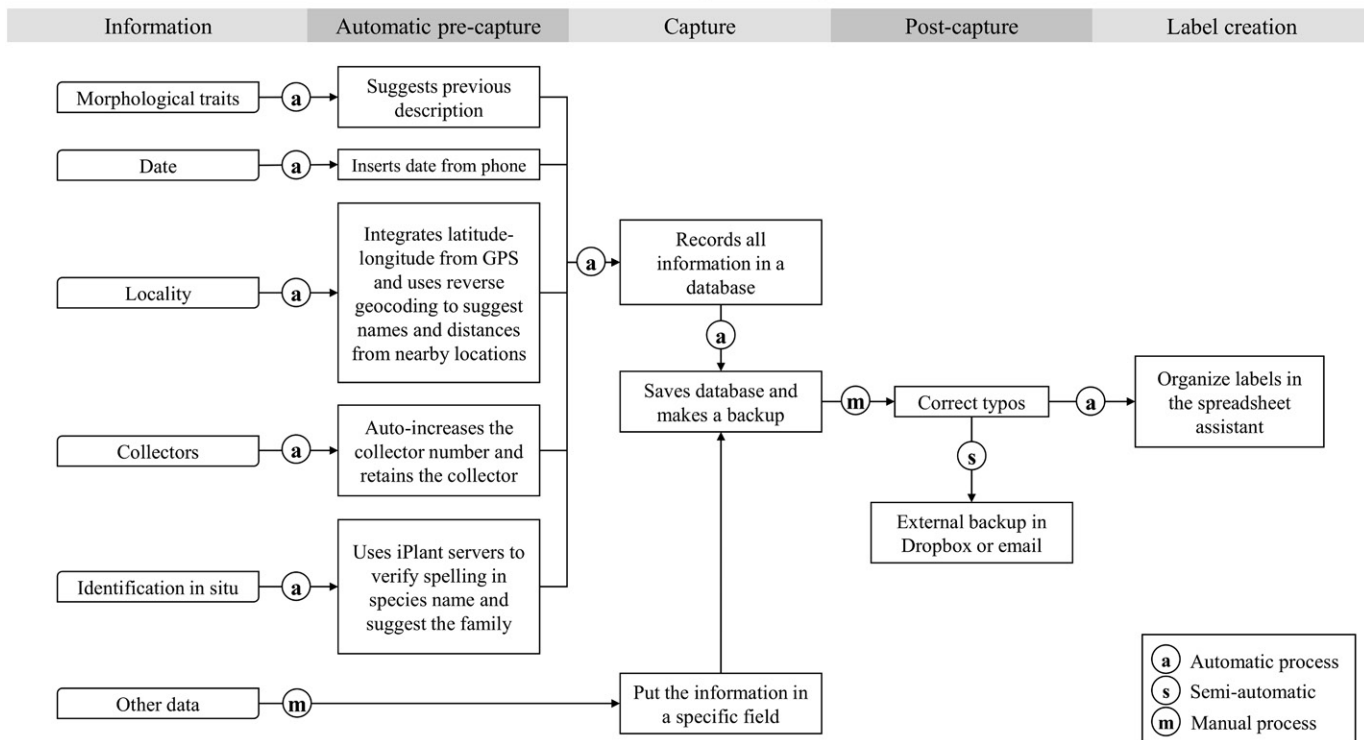**B** **Flow chart for data capture using ColectoR**

Fig. 1. Flow chart of the data capture processes in which the pre- and postcapture actions are illustrated and compared (A) using a common field notebook and (B) using ColectoR with emphasis on the automated processes to improve capture time. a = automatic process (processes automatically completed by ColectoR); s = semi-automatic process (processes that need special action by the user, but that are organized and guided by ColectoR); m = manual process (processes that the user must initiate and complete manually).

Drive, or OneDrive are installed, the user can export these services directly, or if any e-mail application is present, the user can send the database as an attachment (this is recorded in comma-separated value [CSV] format in UTF-8 encoding values, easily opened by any text editor, database manager, or Excel). The verification screen allows the user to see the list of records made previously and permits viewing or editing of each record to complete or modify the registry. The registration screen (Fig. 2A, B) contains the most common fields in the description of a specimen (Germán, 1986) for a herbarium (collectors and their numbers, date, identification, morphological description, latitude-longitude, altitude, location information, and notes). Some fields are suggested automatically by ColectoR, such as the date and, after the first use, the collector, additional

collectors (referred to as "et al." in app), country, and description if the same species was entered previously. Additionally, in this screen the user can access the GPS.

Some other apps in the current market can be used to gather information using smartphones; some of them, like iNaturalist (iNaturalist developer team, 2016), provide a good platform to share observations on the cloud but lack the specific functions and helpers (like autopopulated fields and export functions for herbaria labeling) to become a botanist-focused tool. Additional tools (see suggested list in Bruna, 2011), such as EpiCollect (Aanensen et al., 2009) and Open-DataKit (Brunette et al., 2013), can provide a powerful platform to develop a specific database collector, usually intended for commercial or government use,
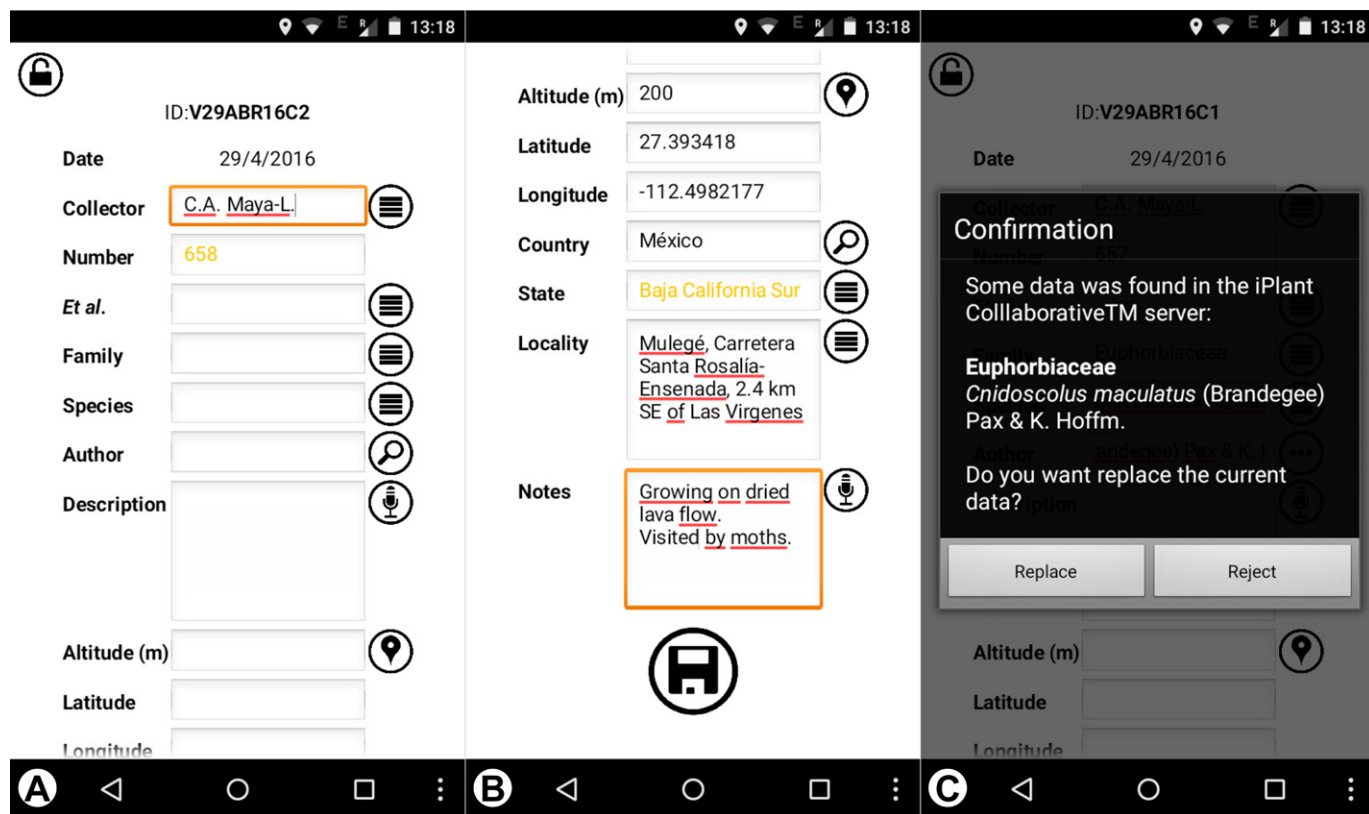
Fig. 2. (A) ColectoR registration screen, with the common data included for a voucher specimen. Each field is followed by icons such as: list icon (shows an autopopulated list based on previous entries), search icon (searches information using some APIs), microphone icon (accesses the Android native speech recognition system), and location pin icon (accesses the GPS and integrated APIs). (B) Bottom part of the registration screen showing the suggested geographic information. (C) iPlant API results shown in a popup window.

but these tools require advanced knowledge and time to develop a particular solution. ColectoR instead was created as a specialized tool for botanists to collect data and label plants for herbaria collections.

Sensors used by ColectoR—The use of information from each sensor varies among smartphones depending on its capabilities; therefore, if the smartphone does not have a particular sensor, the automatic function related to it for obtaining a particular data option will be limited or nonexistent. The application can acquire latitude and longitude for a collection using the GPS tool, as well as altitude in phones with a built-in altimeter (Fig. 2B). This information is used by the application to suggest location data if the cellphone is connected to the cellular network or save it for later use in an offline mode. Because the active GPS causes extensive battery power drain, I designed a save-energy function such that this sensor only operates when accessing the registration screen. Another sensor used by ColectoR is the microphone, which gives ColectoR the ability to recognize dictations using the voice recognition engine integrated into Android to capture descriptions or notes. ColectoR does not record any audio, it is only used for text recognition. Depending on the device, this function will be available only when it is connected to the cellular network.

Integrated application programming interfaces—Communicating through a cellular network, ColectoR can use the internet where there is coverage and obtain information using some integrated application programming interfaces (APIs), as well as backup the primary database. APIs constitute relevant mechanisms that permit ColectoR access to integrated functions in packages or software developed by other programmers or companies. Each API connected with the application has a specific function. One of the APIs used by ColectoR is iPlant Taxonomic Name Resolution Service (Boyle et al., 2013); ColectoR uses the databases available on iPlant servers to verify or correct species names, as well as to autocomplete family names and author fields based on the species information (Fig. 2C). Using three geographic APIs, ColectoR can suggest location information for each collection. Basically, ColectoR uses Google Maps

reverse georeferencing (Google Company, 2016) to obtain the distances by road between the location of the collection and the nearest villages or small cities (designed for long field trip collections); these villages are located using the GeoNames API (GeoNames Team, 2016). Finally, the application can use Bing Maps Locations API (Microsoft Corporation, 2016), which gives information about names of municipalities, counties, departments, and lower political divisions (the level of detail in the information can vary depending on the country and the state). Although ColectoR has many functions that require a connection to the internet via a cellular network, it can still function to hold information that can be accessed in the offline mode. Offline functions include auto-populated lists, auto-increasing collector numbers, access to sensors like GPS, and others. Some fields (e.g., location) can be searched again when access to the internet is restored.

Automatic tasks—Everything in ColectoR was designed to maximize speed, and for that reason some tasks are automatic. In the species field, if the user enters a name like "*Euphorbia polycarpa* var. *polycarpa*," ColectoR will interpret it as a species with an infra-taxonomic identity. In the final database, there is a column for each genus, specific epithet, and infraspecific category and name. If the user describes an identified specimen, in the next collection of this species ColectoR will suggest the same description. It is especially useful for biogeographic studies where the collection of the same taxa is repetitive and only some characters (e.g., size and color) change. Data that typically do not vary in a single field trip are suggested by ColectoR so that this information does not have to be re-entered for each collection. The application also suggests a number for each collection based on the previous number in the database.

An integral part of the automated postcapture data processing is an Excel spreadsheet designed to fit perfectly to the database generated by ColectoR. An assistant for label printing, it is simple enough to be used by entry-level users of Excel and permits labels to be printed for herbarium specimens in just a few steps. Additionally, the spreadsheet can be used to verify, correct, or improve each registry recorded in the main application. The basic design for a standard

label is included in the current version of the Automatic Label Printer for ColectoR, and it contains the most-used fields and a generic layer for herbarium specimens.

Availability and compatibility—ColectoR is available for free at http://camayal .info/colector.htm and is compatible with Android smartphones version 3.0 or later. The assistant for label printing is also available for free at http://camayal .info/automatic-label-colector.htm, and this spreadsheet is compatible with Excel 2010 or later. Both the application and spreadsheet are available under a Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0) license. The source code is available at https://github.com/camayal/colector-AT-AppInventor. Future plans for ColectoR include migrating the development to an additional programming language that permits release of a version for Windows Phone and iOS systems.

CONCLUSIONS

ColectoR includes a number of tools and mechanisms that permit quick data entry in the field. It is set apart from related apps in the current market by offering specific functions oriented to voucher collectors in the botanical community. ColectoR features auto-fill helpers that improve data capture and labeling, stores data that typically do not change in the same field trip, auto-increases the collector numbers, allows users to include information from previously entered data, and offers auto-complete suggestions for previously entered information. This is a lightweight app that manages energy consumption of sensors like GPS and altimeter in a smart way. Using interconnected internet applications, ColectoR gives the user suggestions of names, locations, and distances. The application permits the backup of all information on a file that can be saved in the external nonvolatile memory to secure data in case the battery is depleted or can be exported using the sharing feature integrated into Android for cloud-based storage. The database is minimalist and saved in a generic format (comma-separated value format or *.csv) so that data can be saved using limited data plans. ColectoR was designed to reduce the time used in field data capture, as well as the time used to organize the information postcapture. ColectoR was ideally designed to work on a wide variety of smartphones and was tested in some of the most common devices (e.g., Moto G, Moto E, Acer Iconia, LG C70, Huawei Y250) and also in different versions of Android (Jelly Bean, KitKat, and Lollipop). However, the great diversity of devices, configurations, and hardware specifications that exist in the Android ecosystem can be a disadvantage for some users, because the availability of some functions may vary from one device to other. For example, Assisted-GPS (A-GPS) can be inaccurate and sometimes is not accessible in the field for some smartphones. Because ColectoR works under a limited permit operating system and cannot have full control of folders in the devices, the user must be careful using some cleaner apps that can intentionally delete the database to release space in the memory.

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