Multidimensional Information Visualization on Snakes Characteristics

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***Abstract*—This paper describes how information visualization techniques can be used to find out correlations between certain characteristics on serpents, including their appearance (skin pattern), what it feeds on, dentition type, activity time, habitat, subjugation method and taxonomy. Data are obtained from serpent species present in southern Brazil.**

I. Introduction and Motivation

Snakes (reptiles of the *Serpentes* suborder) are numerous in species. They are present on every continent, except Antarctica and some islands (notably Ireland, Iceland, Greenland, Hawaii and New Zealand) [1]. Some aquatic species live in the Indian and Pacific oceans as well.

Given how numerous and widespread they are, it is natural that snakes are a well-studied subject. The amount of data available about them is huge and easily found – The Reptile Database [2] being a good example. However, we do not know of any work that uses visualization techniques to find out correlations between certain characteristics in snakes.

Some of these characteristics are known by biologists to be related with another. For example, all snakes with solenoglyph dentition are venomous, and all vipers (*Viperidae* family) have keeled scales.

However, certain correlations are not immediately obvious. For example, there are certain snake species (such as the *Calamodontophis paucidens* and the *Tomodon dorsatus*) that are semi-venomous, however, they feed only on small mollusks, which they swallow alive and shouldn't need any venom.

It is also desirable to find out correlations between the snake's skin pattern, its habitat, activity time, what it feeds on, and other variables.

In order to identify these correlations, data visualization methods are desirable.

II. Related work

The Snake Database [3] contains data we could use, however, very few characteristics are catalogued: only common names, taxonomy, toxicity, whether the snake uses the constriction subjugation method, and maximum length.

The Reptile Database's [2] data can also be downloaded; however, it too includes very few data relevant for this study.

We were unable to find any other database on snakes, or any other study that uses visualization techniques for snakes' characteristics.

III. Data

The first step in our visualization is to acquire data. Most resources present information about snakes verbally (generally, books), not on a data table. There are over 3600 snake species catalogued on The Reptile Database (as of July 2017) [2]. It would be tremendous work to assemble data about all these species. Thus, we decided to limit the scope geographically.

In the state of Rio Grande do Sul, southern Brazil, there are dozens of snake species, at least 81 of which have been identified and catalogued in the book *Serpentes do Rio Grande do Sul* [4]. In the aforementioned book, these 81 species have been described as accurately as possible, verbally.

All snake families are present in this region, with the exception of *Pythonidae*. Thus, we have decided to limit the scope to this specific region, using information available from the book.

The first step then is to put all available information from the book into a data table. Because the book's description of each species is verbal, some characteristics had to be simplified, or clustered, so that data analysis is easier.

A. Diet

The first characteristic that had to be clustered was their diet. Verbal description found on the book typically describes what families or orders of animals the snake eats, such as "small lizards, amphisbaenians, birds, and snails". If we included each of these as separate strings, there would be dozens of fields, however, many of them are related. For example, most snakes that eat toads would also eat caecilians, which are both amphibians.

Therefore, we divided diet on the following categories.

- **Amphibians**: Incorporates all amphibians, such as frogs, toads, salamanders and caecilians.
- **Reptiles**: All reptiles have been condensed into this category, except snakes (which have their own category).
- **Fishes**: Self-explanatory.
- **Arthropods**: Self-explanatory.
- **Birds**: Self-explanatory.
- **Eggs**: Bird eggs.
- **Snakes**: This snake species eats other snakes, possibly its own species as well.
- **Rodents**: Small rodents, such as rats.
- **Mammals**: Small mammals, such as rabbits, capybaras, and possibly larger mammals.

- **mollusks**: Typically, snails.
- **Worms**: Typically, earthworms.

Furthermore, these categories have been assigned into two groups: *Large* and *Small*. *Small* animals include amphibians, arthropods, mollusks and worms, while *Large* animals include the opposite. Then, a field was created, that says whether a snake feeds only on *Large* animals, only on *Small* animals, or both *Small and Large* animals.

It is also worth mentioning that all snakes are carnivorous.

B. Skin Pattern

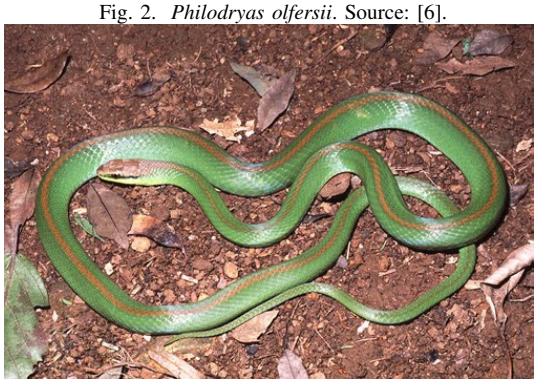
With the help of a herpetologist, we have divided the snakes skin pattern in the following five categories. Note that we only considered the dorsal (visible) side of the snake, because it is difficult to find pictures of their ventral side (underside), and also because it typically not visible. We also did not take into consideration the head or tail pigmentation, for simplification purposes.

- **No Pattern**. The snake shows no pigmentation pattern, consisting only of a single solid color (see figure 1).

Fig. 1. *Philodryas aestiva*. Source: [5].

- **Longitudinal Stripes**. The snake shows one or more stripes aligned along its body, that go from neck to tail or from head to tail (see figure 2).

Fig. 2. *Philodryas olfersii*. Source: [6].



- **Transversal Stripes**. The snake shows many stripes aligned perpendicularly to its body axis, also known as "rings". These rings may be in two alternating colors, or may be in multiple colors. Typical examples include corals and false corals (see figure 3).

Fig. 3. *Micrurus altirostris* (coral). Source: [7].

- **Spots**. The snake shows regular (similar) shapes on its body, often elliptical (see figure 4).

Fig. 4. *Liophis miliaris*. Source: [8].

- **Complex**. When the pattern is neither of the above, it is categorized as "Complex". Typically, this includes intricate camouflage patterns, that would be even hard to describe verbally, or numerous different shapes on its body (see figure 5).

Fig. 5. *Bothrops alternatus*. Source: [9].

Then, looking at pictures of each snake species, we assigned a single skin pattern category to it. If a snake presents two skin patterns (for example, when a snake's pattern has both

longitudinal stripes *and* spots), we assigned the most visible one.

C. Other data

Other data that have been extracted from the book and added to the data table are:

- **Taxonomy**: Each snake is categorized by its taxonomic family, genus and species.
- **Teeth type**: there are four teeth types available in snakes: aglyph, opistoglyph, proteroglyph, and solenoglyph. Snakes with aglyph dentition are not venomous; opistoglyph and proteroglyph are semi-venomous, and solenoglyph are venomous. Each species has one specific dentition type.
- **Activity time**: period of the day that the snake is active. May be either diurnal, nocturnal, or both.
- **Habitat**: Where the snake lives or is active. May be aquatic (in or near lakes and rivers), arboreal (on trees), fossorial (caverns, under foliage, etc.) or terrestrial (on land). Each species may have multiple habitats assigned to it.
- **Subjugation type**: How the snake subjugates its prey. May be swallow alive (the snake swallows its prey whole and alive, without killing or weakening it first), by constriction, or envenomation. Each species may have multiple subjugation types.
- **Size**: Average or maximum size of an adult snake, in centimeters.

Data that are unavailable in the book were left blank (in the case of numeric entries) or assigned the value "Unknown" (for categorical entries).

A visualization was then created to view all these data at once.

IV. Visualization techniques

All of these data have been added to a single linked-view visualization with multiple charts (see figure 6). We have chosen stacked bar charts for wide characteristics (Feeds On and Habitat), and pie charts for narrow characteristics (all others). Tooltips on mouse over reveals information on what each color represents.

One characteristic was originally wide, Subjugation Type, which could be any combination of Swallow Only, Constriction and/or Envenomation. We made it narrow by creating the following fields: Swallow Alive Only, Constriction Only, Envenomation Only, Swallow Alive or Envenomation, and Constriction or Envenomation. Other combinations were not needed because no snake uses another combination of subjugation method. This was done to make filtering easier.

Clicking on any chart will filter all other charts in the visualization. Thus, by selecting multiple filters, it is possible to find correlations between different characteristics.

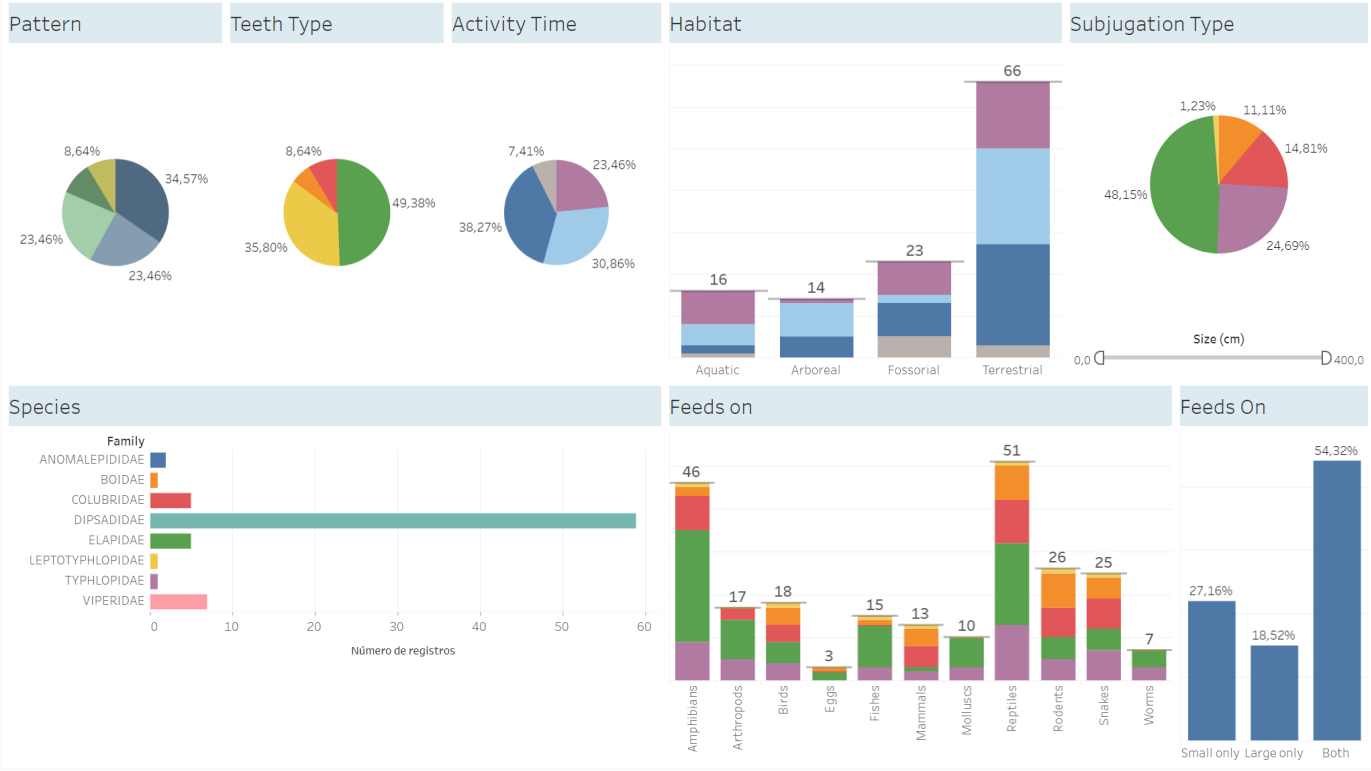
V. Results

Before applying any filters, certain characteristics are evident on Rio Grande do Sul snakes as a whole. Most of them have terrestrial habitat (81.4%), roughly half is non-venomous, roughly half swallow their prey alive, 56% prey on amphibians and 62% on reptiles.

After applying several filters in different combinations, we have come to the following insights. See the references for a snapshot of the corresponding visualization, to see which filters were applied.

1) Most snakes (85.72%) with a Transversal pattern are venomous [10].
2) All snakes with the Spots pattern may swallow their prey alive, and 25% may also use venom [11].
3) All snakes who use venom, constriction, or both to subjugate their prey have either pure nocturnal (72.73%) or diurnal/nocturnal (27.27%) habits, but never purely diurnal [12].
4) Snakes who only swallow their prey alive tend to have more diurnal habits (43.59%) [13] than the others (19.05%) [14].
5) The average size of snakes with both diurnal and nocturnal habits is 87.56 cm, while those with purely diurnal or nocturnal habits measure an average of 111.5 cm – a difference of about 21% (reference: tooltip on chart "Activity Time").
6) Venomous snakes (both proteroglyph and solenoglyph dentition) always use venom to subjugate their prey; they never try constriction or swallow alive [15].
7) 68.97% of snakes with opistoglyph (semi-venomous) dentition may swallow their prey alive as subjugation method, and 31.03% may use constriction. But all of them may also use venom as well [16].
8) 97.5% of snakes with aglyph (non-venomous) dentition swallow their prey alive (and feed on small animals), while 2.5% use constriction (and may feed on large animals as well) [17]. However, this 2.5% represents only a single species – the *Eunectes notaeus*, a large constrictor boa.
9) Snakes who feed on *Large*, or both *Small and Large* animals, tend to be venomous (61.02%) [18]. However, this is another regional characteristic, as there is only one boa species in the region (boas are large and non-venomous snakes).
10) Of the snakes who only swallow their prey alive as subjugation method, 41.03% feed exclusively on *Small* animals, while 58.97% feed on both *Small and Large* animals [19]. Naturally, the average size of these two groups is significantly different: 55.44 cm for the first group, 106.14 cm for the second.
11) All snakes from the *Viperidae* family have complex pattern and exclusively terrestrial habitat; 85.71% have only nocturnal habits (14.29% both nocturnal and diurnal), and all of them prey on rodents (as well as other small and large animals, to a lesser extent) [20].
12) Snakes from the *Dipsadidae* family prey mostly on reptiles and amphibians. In addition, roughly half has aglyph (non-venomous) dentition and half has opisto-

Fig. 6. The visualization.



glyph (semi-venomous) dentition [21].

We asked an herpetologist if any of these correlations were already known. She said insights number 1, 6, 9, 10 11 and 12 were. All others represent new knowledge.

VI. Conclusions

The visualization allowed us to discover information that would be otherwise difficult or even impossible to determine by just looking at the data table. Although the data set is a bit restricting – there are no pythons and only one boa species, for example – we believe much more could be learned if a larger data set was available. Even with the current data set, we are certain much more could be learned by applying different filters.

The herpetologist who worked with us was also excited about the possibilities of this tool, particularly with a larger database.

Of course, we must also take into consideration the reliability of the source data. There are 81 species catalogued in *Serpentes do Rio Grande do Sul*, but we cannot assume that all of these species have been thoroughly studied. It is possible that certain fields have incorrect values. For example, some snake species with proteroglyph or solenoglyph dentition may use the constriction subjugation method after all, this behavior just wasn't observed yet.

For future work, we would like to extend the source data to include snakes from a larger region. Another possibility would be to include several samples from all over the world, so that the analysis represents a global average, not a regional average. Eventually cataloging all snake species in the world would be beneficial as well.

Another update would be to include more data in the data table and visualization, such as skin color(s), relative strength of venom toxicity, which toxins are contained in the venom, conservation status, region where they occur, period of the year that they reproduce and how many baby snakes are spawned, and so on.

The visualization and data table are available for viewing and download at [22]. Tableau version 10.3 was used to create the visualization. Permission is granted to freely use, distribute, modify and expand the visualization, as long as you cite this paper.

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