






Designing an Interactive 2-Level Circular Algorithm to Visualize and Support Collaboration in Science

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Abstract. Researchers are always trying to get the most important knowledge, however, finding accurate results in the current science deluge have never been more critical than now. While information technologies have changed the way we collect, store and retrieve information, there is a lack of strategies that support the exploration and presentation of scholar knowledge. Circular layouts are well-known structures for visualizing relations between entities, and as opposed to force direct layouts, are a more effective and user-friendly solution for visualizing relationships. This article presents a novel 2-level circular structure to map and support cooperation in science communities. The 2-level circular layout was designed and implemented using D3.js and is able to depict the relations between two different entities: the community that falls within a specific knowledge area (outer circle), and the articles curated by the community (inner circle). The goal is to support a collaboration scenario between researchers, who in turn share important knowledge based on their reading experience. The 2-level circular structure provide an overview plus details of the relations between these two entities. The preliminary results provide interesting results and pave the way for future research on a two-level layout. The link to access the visualization and code can be found at the end of the article.

Keywords: Design · Information visualization · Circular layouts

1 Introduction

Finding accurate results in the actual digital information deluge is a big challenge and has never been more current than now [1]. This challenge imposes a shift from the actual research approaches that are based on search engines mechanisms defined by advanced search strategies, to a solution based on a visual language that supports and portrays science cooperation [2]. In science digital libraries context, a visual strategy to support the research process is lacking, which underlines the importance to design effective and efficiently solutions that simplify the digital systems we use. A recent article proposes a new type of visualization tool as a data scope, and compares our current capacity

to understand and visualize large sets of data to the 17th-century astronomy evolution accomplished by Galileo [3]. In the past, researchers didn't have powerful tools to capture the different layers of our complex, dynamic and multidimensional world. Drawing was the primary medium to communicate observations, ideas and conceptual theories [3]. Such examples are the cholera map of London (1854) from John Snow, Charles-Joseph Minard's map of Napoleon's flawed Russian campaign of 1812, Florence Nightingale and the Nightingale Rose among other information visualization drawings/milestones [4–8]. Currently, and through the use of our contemporary tools and technologies it is possible to explore the actual information landscapes¹, with more resolution [3]. These new tools give rise to a new medium and a new way of understanding complex phenomena, while providing new forms of communication [3, 9]. Information visualization (InfoVis) is a novel medium [9] that provides the techniques and an abstraction process for better understand the social dimension of science [10, 11]. The presentation, and communication of scholar knowledge defines an urgent and ongoing challenge [1], and underlines the importance to establish a synergy between Communication/Information Design and InfoVis [12, 13]. However, adding the social dimension and a collaborative approach based on the wisdom of crowds supported by a visual language that translates these interactions makes the challenge even more complex from a design standpoint. Thus, is important to design user-friendly solutions by merging attractiveness, clarity, aesthetics and (perceived) usability [14].

A growing number of exploratory interfaces have emerged, but with no practical results for the main actors in science [15]. Therefore, is important to understand first which visual language and information structures could support the described scenario. A set of categories defines advanced InfoVis approaches. Hierarchical and relational visualization structures are defined by node-link diagrams approaches, making it possible visualize relations between entities. Nodes and links define the visual encoding strategy (visual marks), and a set of algorithms must be considered to visualize specific type of relations. Vertical, horizontal or containment algorithms (e.g., Treemaps, Sunbursts), commonly referred to as trees, are used to visualize hierarchical relations. Non deterministic algorithms (e.g., Force-directed layouts) or fixed layouts are used in network visualization. The focus of this article is on network visualization and on a specific type of layout, namely circular layouts. The next section provides a brief study of circular layouts that are a more user-friendly approach to visualize networks.

1.1 Circular Layouts

Circular layouts are a distinct category of techniques to visualize networks. Node-link diagrams techniques fall into two main sub-categories, namely force-directed layouts [16–19], and fixed layouts that have three sub-categories, namely grid, linear and circular/radial [12, 20–22]. The main focus of this article is circular layouts, where the node's fixation placement determines the layout strategy [21, 23]. An early example of a circular layout is the circular relation map proposed by [24]. Circular layouts are an optimized approach for portraying complex information, and are a common approach

¹ Information Landscapes: Muriel Cooper at the TED5 Conference.

in visualizing social networks and ontologies. The process of efficiently visualize relational structures between entities, and also between different categories, results from a simple design approach: the nodes placement occurs at specific locations in contrast to what happens in non-deterministic layouts that, for the same input, it may produce a different output in different runs. In circular layouts, nodes are placed equidistantly along the circle, so it is possible to have a cleaner and uncluttered layout, allowing nodes and links to have more visibility [25]. The link placement usually happens in the center of the circle and depicts the relations between nodes.

A disadvantage of circular layouts is the number of links displayed in the center of the circle, specifically when there are a considerable number of links. One mitigation strategy to overcome this problem, and achieve readability is the use of clutter reduction techniques, such as the edge bundling technique where similar edges are grouped together into bundles [26]. The goal of previous approaches was to find better and more efficient circular drawing techniques to minimize the number of edge crossings [27–29]. The work of [30] point out important references of early circular layouts or layouts with a connected ring pattern, and emphasizes important concepts.

This brief study provides important strategies and clues for the two-level layout design and implementation process, taking into consideration a specific scenario that is presented in the following section.

1.2 Future Usage Scenario for the 2-level Circular Layout

The conceptualization of the two-level layout was based on a context in which the potential future use of the algorithm is illustrated through a specific scenario. User experience is related to context issues, so scenarios are context-specific. The process of drawing and describing scenarios is a fundamental approach to predicting potential problems, discovering opportunities, and understanding how users interact in a particular context [31]. This section provides the scenario that shaped the conceptual basis for the two-level circular layout design. It is also discussed the promising benefits in using this structure in a future exploratory interface for science [32].

Digital science libraries (e.g., ACM digital library, IEEE Xplore) provide search and retrieval services, and researchers use these services to find important results according to their specific research topic. Despite the significant advantages of science digital libraries mechanisms, the exponential growth of articles [33] makes searches time-consuming [34] and the actual support that is provided in the search process is very limited and based on an extensive list of results [35]. Such an example is if an inexperienced or experienced researcher is new to a topic and knows nothing about the topic, researchers may simply feel overwhelmed and therefore waste a lot of time trying to find accurate results. The visual approach of these libraries is based on extensive lists of results, which makes it impossible to get a complete view and depth on a complex topic at a glance (e.g., COVID-19 topic) [2]. Therefore, the visual approach of digital libraries is not in line with one of the fundamental principles of InfoVis, that is the process of representing data in a visual and significant approach so that a user can better decode it by “displaying data for at-a-Glance monitoring” [36–38]. Therefore, science digital libraries interfaces are not an effective solution when dealing with complex topics, as for instance the Covid-19 articles flood [39, 51]. Researchers are easily drowned in an information deluge, and not

finding important results have a big impact in the research process (e.g., literature review process). Researchers normally select the most important according to a non-transparent metric (e.g., relevance and ranking metrics), and therefore the probability of selecting the remaining publications is very reduced [40–43]. A broader discussion of the metrics used in science digital libraries is beyond the scope of this article. The highlighted issue makes an urgent need to design solutions and strategies based on Communication and Information Design, and Information Visualization approaches.

Another facet that is added to this scenario is the fact that science is also described by a social dimension² [44], where researchers based on a personal curatorial process, when asked by their peers, share important publications based on their reading experience [31]. In fact, researchers usually read a set of articles and save these articles, the most important ones according to their specific interest, on their personal computers to cite or to use later. The initial question states that if we share these articles with our peers, rather than “keeping” them on our personal computers, we can have an efficient social filtering process, where researchers provide a research synthesis based on their personal reading experience [45]. Thus, the described scenario discloses fundamental clues about the topology of science social cooperation [46–48]. In fact, science is a community-based social activity, that equally happens in the digital space, where are communities of researchers who are willing to share and assist each other’s. An example of science social cooperation is when researchers request to their peers’ important publications on a specific topic. Therefore, the described scenario sets out the context and the visualization goal, where a collaborative process must be supported, abstracted and mapped out through a structured communication process.

To address this challenge, we propose an information visualization structure that could be incorporated into a future exploratory interface for science [32], namely a novel two-level circular layout to portray the links between one specific science community and a set of articles based on researcher’s personal experience. The implemented prototype uses a dummy dataset that simulates the presented scenario.

The advantage of the propose layout, and compared to a force direct layout, is that it is possible to more clearly visualize the connections between two different entities. This approach is also supported by interaction techniques that will be discussed in Sect. 2.1.

The remaining article is divided in the following sections: Sect. 2 describes the design and implementation process of the novel interactive two-level circular layout/algorithm in D3.js, and Sect. 4 provides some preliminary results. The last section presents a brief discussion and future directions. The Observable link to access the visualization and code can be found at the end of the article.

² Science Dimensions: Social dimension: people, institutions; Institutional dimension: rules, funding, metrics, indicators; and Cognitive dimension: texts, journals.

In the mapping strategy, visual marks are used to represent data items, namely points and lines that represent nodes and links. In the visual encoding strategy, namely the visual channels, color intensity, hue, and position are used. In the outer circle structure, it is used text instead of the visual mark circle (node). The objective is to provide a fast distinction between two different items, namely researchers and articles.

The articles are sorted according to a hypothetical score that defines the number of articles placed in the inner and outer circle (e.g., ponderation factor) [45], the same approach takes place in the researcher's circle (outer circle). A further discussion about the score/ponderation factor is beyond the scope of the current article [45].

The layout represents the connections between the articles and the researchers. The link gradient allows to visualize directionality between researchers and articles or vice versa. To represent the dynamics flows metaphor it was applied a transition with 7 s between the color hue of the outer nodes (e.g., color: #ee2681) and the colors hues of the inner nodes (e.g., blue, magenta, purple). However, at this point, the animation flow does not represent any kind of variable³, further research is needed regarding to this point.

The link between the two items is specified using the `Value` attribute that stores the name of the items. The `title` attribute of the article that is shared, is stored in the value array of each researcher.

Color was used to simplify category identification, and is based on Lch/HCL color space interpolation that is both intuitive and perceptually uniform [49]. The transformation from RGB to Lch/HCL interpolation space, was performed in the Leonardo color webtool⁴, and the color scheme was generated in Coolors⁵ webtool. A further discussion about the color topic is beyond the scope of the current article.

2.1 Circles Radius and Nodes Distribution

The circles are based on the `circle_gen` function to generate the position of items, persons and objects, based on cartesian coordinates (x, y) rather than polar coordinates. The function performs the nodes computation and the equidistant distribution along the circumferences based on the x and y coordinates. Succinctly, the function uses a set of attributes, namely, `data`, `gen_radius`, `transform_text`, `scale_color`, `inc_angle`, and `type`.

The `data` attribute is related to the data needed to draw the circle, namely the item persons (researchers) which is sorted alphabetically and the item objects (articles) which are grouped by knowledge domain clusters and a hypothetical score; the `gen_radius` defines the radius of the circles (e.g., outer circle slider button: max 1000 px, min 600 px; inner circle slider button: max 900 px, min 200 px) see Fig. 2; `transform_text` is the text size and padding parameterization; the `scale_color` defines the nodes color scale, however has not been used, because every item in the dataset contains itself a color; `inc_angle` defines the division of the circumference by the number of equidistantly distributed items, and also the node angle on the circles using the following function:

³ Use google chrome to view the animation.

⁴ <https://leonardocolor.io>.

⁵ <https://coolors.co>.

```
2*PI/n (e.g., array(person; array(object).length;
```

The attribute `type` performs the distinction between items, namely objects (articles) and persons (researchers).

The distribution of the items based on cartesian coordinates is performed using.

`object_id` that is the identifier of each item and makes the distribution of the nodes equidistantly. This value is multiplied by `inc_angle` to determine the relative angle of the node on the circle. This converts the node angle and radius values to cartesian coordinates based the following functions:

```
new_object.x = gen_radius * Math.cos(object_id * inc_angle)
new_object.y = gen_radius * Math.sin(object_id * inc_angle)
```

The Cartesian coordinates are thus applied to the following function that calculate the positions of the nodes in order to generate the circular structures:

```
node.append('circle').attr('cx', d => d.x).attr('cy', d => d.y).
```

However, to obtain the attributes required for the links computation, the map type called `coor` (coordinates) associated with the items objects and persons is used. A set of attributes define the value `map`, namely the cartesian coordinates and the `uid` performs the link identification.

The connections between the items are based on two attributes, namely `source` and `target`. An array with links was implemented to store attributes related to the cartesian coordinates of the `source` and `target` attributes (persons and objects). The nodes placement it is based on arrays, namely `array object` and `array person`. This solution provides scalability to the structure. Adding new items with their respective array makes it possible increment the number of levels/circles.

To reduce internal visual clutter, the technique edge bundling without hierarchy was used. This approach differs from the hierarchical edge bundling technique [26], because it uses a relational dataset structure rather than a hierarchical dataset. The non-hierarchical edge bundling implementation was based on the following code⁶:

⁶ <https://stackoverflow.com/questions/34263110/d3-js-edge-bundling-without-hierarchy>.

```

.attr("d", function(d) {
    var lineData = [
        {
            x: Math.round(d.target_x),
            y: Math.round(d.target_y)
        }, {
            x: Math.round(d.target_x) -
Math.round(d.target_x) / 2,
            y: Math.round(d.target_y) -
Math.round(d.target_y) / 2
        }, {
            x: Math.round(d.source_x) -
Math.round(d.source_x) / 2,
            y: Math.round(d.source_y) -
Math.round(d.source_y) / 2
        }, {
            x: Math.round(d.source_x),
            y: Math.round(d.source_y)
        }
    ];
    re-
    turn`M${lineData[0].x},${lineData[0].y}C${lineData[1].x},
    ${lineData[1].y},${
    {lineDa-
    ta[2].x},${lineData[2].y},${lineData[3].x},${lineData[3].
    y}`;))

```

2.2 Interaction

Interactivity plays an important role in exploratory information visualization approaches. A click on a node provides only the links between articles and researchers, and also removes the tooltip and the remaining nodes see Fig. 2.

The users can use the mouse wheel to change the scale of detail through the zoom technique; two range slider buttons are used to change the radius of the outer and inner circle; the *connections on* button activates all the links and provides the context overview, and the *connections off* button clears the structure as shown in Fig. 3.

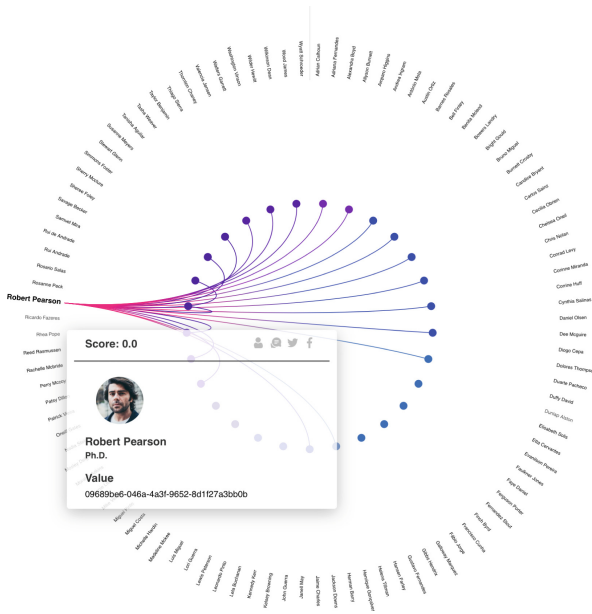


Fig. 2. Researchers tooltip

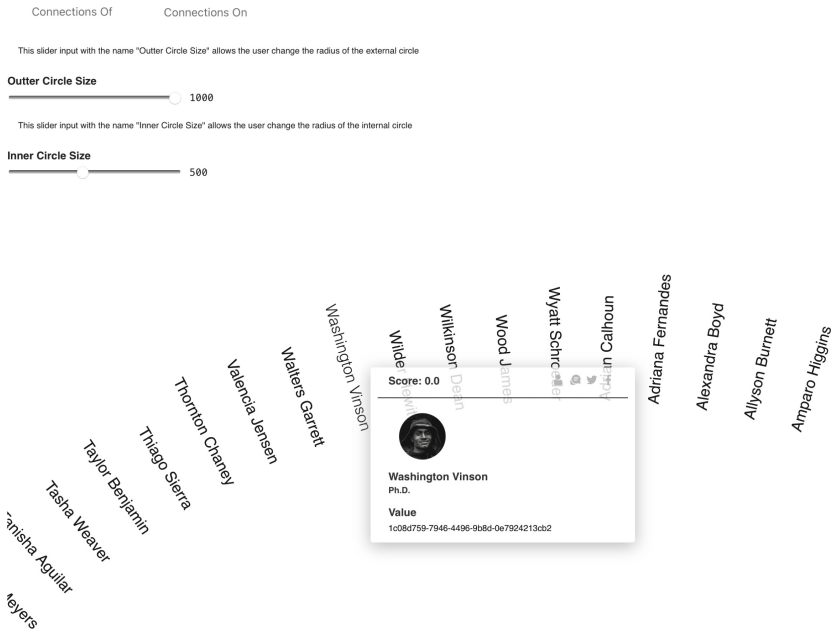


Fig. 3. Range Sliders

It is important to note that the buttons (*connection on* and *connections off*) are not the final design, a new design will be proposed in future work.



Fig. 4. Articles tooltip

A mouseover event triggers a tooltip/infotip to display detailed information/ metadata related to researchers and also related to articles (e.g., Title, Authors, Year among other metadata) as shown in Fig. 2 and Fig. 4. Another visual feature is the transparency of the tooltips that is used to prevent users from losing sight of the context.

The outer nodes (researcher’s nodes) are arranged alphabetical and clockwise from the central axis of the circular structure.

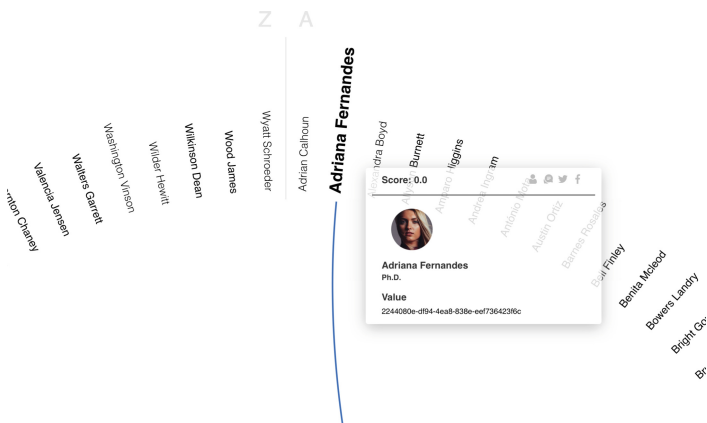


Fig. 5. Reference line

The reference line with the letters A and Z is used to indicate the start and end point of the circular structure. The aim is to reinforce a clockwise orientation/reading process of the structure as shown in Fig. 5.

An important technique is to visually “gray out” the context to reduce visual clutter. Opacity with a value of 0.07 was used to make the context transparent, as shown in Fig. 6. This technique makes it possible to focus on a node and its respective links without letting users lose sight of the context, and thus provide a continuous and predictable experience as the interface context changes.

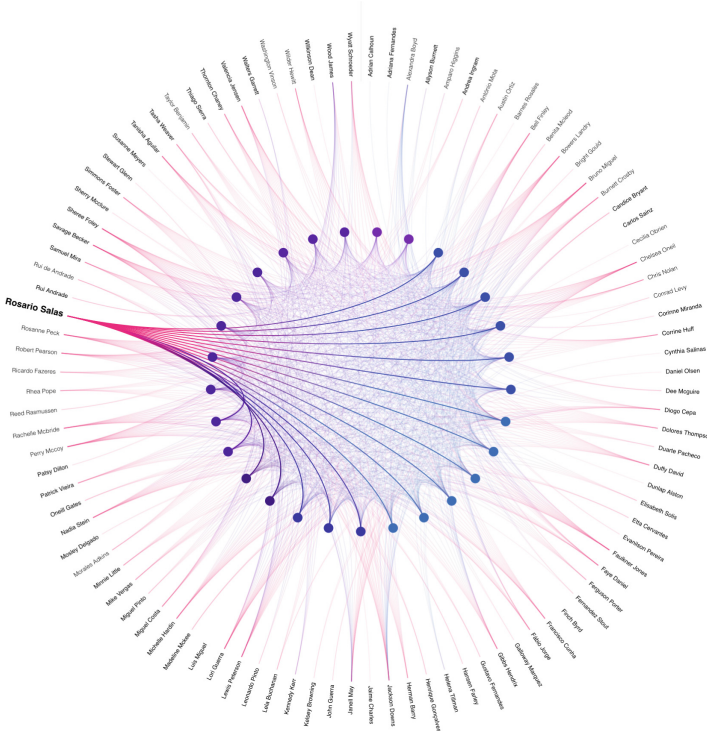


Fig. 6. Interaction

We believe that a clear design as well as the implemented interaction techniques will better support the user’s exploratory activity.

3 Preliminary Results

The main goal of this paper was to describe the process of conceptualizing and implementing a two-level circular visualization structure in D3.js, given a specific scenario. This section presents some preliminary results of the two-level circular structure, in terms of user interface design choices, interaction techniques and layout implementation strategies [32, 45]. Section two provided important guidance, namely novel interaction

techniques, and clutter mitigation strategies, such as the hierarchical edge bundling technique [26]. Our approach used a dummy relational dataset structure with 100 nodes in the outer circle, 29 nodes in the inner circle, making 963 links. It was used a dataset with a relational structure, and the items persons and objects are at the same level. D3.js library was used to design and implement the structure, and the layout structure and links were based on Marchese's⁷ D3.js approach, which is also based on a relational dataset structure. This approach solved some problems at the functional level, specifically with the node distribution and arrangement. This work was the basis for the circular and equidistant distribution of the nodes in the two circles. However, our approach differs from Marchese's in terms of aesthetics, functionality, and interaction. Such examples are the use of animation and hue gradients, infotips/tooltips, the use of the edge bundling technique without hierarchy, the use of buttons to change the structure scalability by changing the radius scale, the *on* and *off* buttons to display connections, the use of the zoom in and zoom out technique, used dataset, aesthetics principles and interaction techniques.

The non-hierarchical edge bundling technique reduced the visual clutter between the outer circle and the inner circle. However, with a high number of connections, the inner circle remains cluttered. The first objective was to test whether the technique could handle a high number of connections and crossings in a two-level circular structure, as shown in Fig. 1. In future work, the goal is to improve the technique and achieve better readability by reducing the overlapping between nodes and links. However, more research is needed on this point. The interaction techniques mitigated this issue by "deactivate" the context to reduce visual clutter see Fig. 6. Another point is that the number of researchers and articles will be limited according to a score (e.g., ponderation factor), which will reduce the number of links and thus the visual clutter.

Succinctly, the two-level structure can interactively and aesthetically accommodate social cooperation based on a curatorial process of articles. Interaction techniques allow users to interact and navigate, but also mitigate visual clutter.

The work represents a proof of principle, and the current results are still at a preliminary stage, so more research is needed on the main points highlighted.

4 Discussion and Future Work

This article presents a design approach to science, and the goal is to address the flood of knowledge. The proposed two-level interactive circular structure is an exploratory visualization that aims to support a collaborative and curatorial process based on the wisdom of science communities. This kind of behavior already happens on social platforms, however without a visual logic/language that supports and maps the social dimension of science.

The structure uses two circles, the inner circle represents the most shared articles, and the outer circle represents the researchers who read and share them, according to the described scenario. The computed links provide the connections between these two levels. Is important to emphasize the use of a non-hierarchical edge bundling technique to

⁷ <https://observablehq.com/@juanmarchese/chord>.

reduce visual clutter, however further research directions are needed regarding this point. The social cooperation flows of science are presented metaphorically, as an animation is used, however the flows do not represent any variables, so further research directions are also needed regarding this topic.

In future work, we will design a metadata filter panel and implement a set of properties to reduce visual clutter (filtering mechanisms and ponderation factors). It is important to conduct a user study/evaluation based on performance metrics and satisfaction metrics to understand how researchers will interact and navigate in the two-level circular layout. The study will be conducted with researchers playing 3 types of roles: beginner level (e.g., Ph.D. students), intermediate level (e.g., Post-Doc. Researchers), and expert (e.g., established Researchers and Professors), for a total of 15 testers and according to a set of task scenarios, using the Think Aloud protocol. Important artistic works should also be considered in a future literature review, the work of [50] provides important cues on how to transform digital information into an aesthetic of participative processes. The visualization and code can be found in the following link: <https://observablehq.com/@brunomiguelam/2-level-circular-layout>.

Acknowledgements. This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

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