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Research article

Architecture: explainable artificial intelligence and research into the creative process

Arquitectura: inteligencia artificial explicable e investigación del proceso creativo

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Abstract

Introduction: The Reconstruction and Assessment Methodology of the Architectural Design Process (RAM-ADP) extrapolates that used within the doctoral thesis on the Jesús Maestro Parish Group of Valencia to the study of other architectural projects, it has been systematically implemented by means of a hybrid open access digital entity as a research network and institutional repository (RN-IR), and the intervention of Explainable Artificial Intelligence (XAI) technologies whitin this virtual environment to optimise research (XAIRM) is studied. **Methodology**: Fundamentally, XAIRM strengthens the researcher, whose information and arguments introduction within the RN-IR trains a set of XIAs as agents, who then develop the research tasks, reviewed by the researcher before their validation within this virtual environment by documentary centres, universities, and the owning body. **Results:** The architectural design process organisation within an evolved and semi-automated virtual environment (XAIRM). **Discussions:** XAIRM involves promoting the use of AI guaranteeing information traceability from research on the creative process. **Conclusions**: XAI advanced applications within the RN-IR do not alter human control over the research process and allow the researcher time and effort to be optimised.

Keywords: Corrales; Molezún; Architectural research; Design process; Explicable Artificial Intelligence; RAM-ADP; RN-IR; XAIRM.

Resumen
Introducción: La Metodología de Reconstrucción y Evaluación del Proceso de Diseño Arquitectónico (MRE-PDA) extrapola la utilizada en la tesis doctoral sobre el Grupo Parroquia Jesús Maestro de Valencia al estudio de otros proyectos arquitectónicos, se ha implantado sistemáticamente a través de un ente digital híbrido de acceso abierto como red de investigación y repositorio institucional (RIV-RIT), y se estudia la intervención de tecnologías de Inteligencia Artificial Explicable (IAE) en este entorno virtual para optimizar la investigación (MRIAE). **Metodología**: Fundamentalmente, la MRIAE fortalece al investigador, cuya introducción de información y argumentaciones en el RIV-RIT entrena a un conjunto de IAE en calidad de agentes, que después realizan las tareas de investigación, revisadas por el investigador antes de su validación en el entorno virtual por los centros documentales, las universidades, y la entidad titular. **Resultados:** La ordenación del proceso de diseño arquitectónico en un entorno virtual evolucionado y semiautomatizado (MRIAE). **Discusión**: La MRIAE implica promover el uso de las IA garantizado trazabilidad de la información del estudio del proceso creativo. **Conclusiones**: Las aplicaciones avanzadas de las IAE en el RIV-RIT no alteran el control humano sobre el proceso de investigación y permiten optimizar el tiempo y el esfuerzo del agente investigador.

Palabras clave: Corrales; Molezún; Investigación arquitectónica; Proceso de diseño; Inteligencia Artificial Explicable; MRE-PDA; RIV-RIT; MRIAE.

1. Introduction

The doctoral thesis on the Jesus Maestro of Valencia Parish Group (1961-1967) (Mondéjar, 2016) develops a methodology that essentially proposes a detailed cataloging of the original documentation as a control instrument and as a source of evidence for grouping the documentary units into types of architectural elements and design versions, according to the validation criteria of 'internal coherence', 'external coherence', and 'contextual correspondence'. Additionally, the graphic synthesis completes holistically this documentary analysis. Thus, after the methodological application to a specific architectural project, it becomes possible to achieve a rigorous and profound understanding of the creative process, and consequently, a documentarily optimised architectural critique by means of any style of inquiry[1].

On the other side, the application of this methodology provides evidence that allows evaluating the quality of this type of research and its analogues (Mondéjar, 2020). Furthermore, the replicable nature of its categories when analysing the creative process of other architectural projects makes possible the evolution towards its systematic digital implementation: the generic constitution of the Reconstruction and Assessment Methodology of the Architectural Design Process (RAM-ADP), integrated within the digital entity of a mixed nature and open access, the Research Network-Institutional Repository (RN-IR) (Mondéjar, 2023). Based on this approach, knowing that architectural criticism usually occurs after an intuitive selection of the interest centres along the design and construction process, the aforementioned methodology and its digital systematisation would

[1] This methodology is analysed in detail along I Congreso Iberoamericano Red Fundamentos: Experiencias y métodos de investigación (Mondéjar, 2017). Additionally, its application has allowed the discovery of an unprecedented ideal of generation of the sacred space of Corrales and Molezún, explained along II Congreso Iberoamericano Red Fundamentos: Metodologías y Experiencias de Investigación (Mondéjar, 2018).

allow said selection to be argued in detail and progress the research within a global environment, which, additionally, it would be susceptible to experience external assessments and adjust to international standardization criteria.

Added to the above, it is worth highlighting the current emergence and accelerated evolution of generative computing technologies, conventionally named as 'Artificial Intelligence' (hereinafter, AI), which seem to constitute a general paradigm shift due to their extreme adaptability to specific contexts of human activity, and also, due to the enormous potential for information processing and subsequent generation of content. Undoubtedly, refinement of adaptation to the requirements and speed of the automated response by means of algorithms after the demand for specific tasks constitute part of its main attributes, while lack of knowledge of the nature, origin and reliability of the information of the resources used and their connection with the information produced, to a large extent exhibit their most relevant weaknesses.

Taking the above into consideration, there is an opportunity to apply the capabilities of current Artificial Intelligence to the operational scope of the methodology considered to increase the quality of this type of research. Consequently, the objective of this study is to integrate intervention strategies of AI technologies when applying the RAM-ADP methodology within the RN-IR digital environment, to optimise research on the creative process of architectural projects, maintaining the traceability of the information used, from that included within the original documentary units to that produced by generative computing, and connecting it to each other by means of arguments validated by accredited agents, such as researchers, documentary centres and universities.

As a result of the aforementioned integration of intervention strategies of AI technologies in this field of architectural inquiry, it would be possible to significantly reduce the time spent when applying the RAM-ADP within the RN-IRT environment without reducing the rigor of the creative process study, to increase the models of alternative creative processes for each project, and to increase connections between research from different projects, which would facilitate the RAM-ADP use within the framework of the RN-IR and would promote the constitution of a body of knowledge on the architectural design process with the greatest foundation and global scope, supplementary to the existing one, and compatible with any architectural criticism style of research.

2. Methodology

2.1. Previous considerations: configuration of AI technologies within the digital environment RAM-ADP&RN-IR

Fundamentally, the integration of strategies based on AI technologies by means of the application of the RAM-ADP within the RN-IR digital environment (or also, RAM-ADP&RN-IR) would allow the researcher to maintain the functions initially attributed during studies on documentary fragments or procedural processes selected by the researcher, whose performance would constitute the AI model training to be used within the automated processes applied to the rest of the documentation of an analyzed architectural project. For the acceptance of the information units obtained by generative computing, it would be necessary to apply the type of validation that is already established within the RAM-ADP. Derived from the above, the research process would evolve from a verified digital environment to a verified semi-automated digital one, which could imply a quality

increasing of the research, an optimization of material and temporal resources, and as a consequence, greater accessibility to this type of inquiry and greater potential for its dissemination.

As a starting situation, the existence of the RAM-ADP&RN-IR, previously explained in detail (Mondéjar, 2023), is considered as the basic infrastructure that is able to house the original documentation of projects relevant for architectural criticism and research, within which design process from the beginning to the finished building is analysed. This implies the constitution of an open collaborative research network (in line with the Open Access principle[2]), traceable and perfectible, and simultaneously, the constitution of a process and results of the investigation institutional repository[3].

On the other hand, the Artificial Intelligence generative computing technologies considered within this research are based on the following principles:

- The presence of a group of AI technologies or applications within the RN-IR digital entity, generically called AIs (or also, XAIs) within this inquiry.

- Each AI publicises its technical and functional characteristics, the algorithms and programming it presents, as well as the updates it develops over time.

- Each AI has been subject to a selection process by the entity that owns the RN-IR (or simply named 'owning entity') that manages the RAM-ADP&RN-IR prior to its incorporation into the digital entity.

- Each IA that has been selected for incorporation into the digital entity owns the status of accredited AI for the RAM-ADP&RN-IR by the owning entity.

- Each AI is subjected an evaluation process by the owning entity that manages the RAM-ADP&RN-IR along its stay within the digital entity. Consequently, an AI may or may not continue its mission within the RN-IR.

- Each AI owns a specific role along the RAM-ADP development.

- Each AI considers only the information contained within the RN-IR (or also named input information for processing), consisting of the original digitised documentary units of architectural projects, the research of the specific projects creative processes housed within the RN-IR, and the information produced by the AI integrated and accredited within the RAM-ADP&RN-IR.

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[2] Azorín *et al.* (2021) indicate: 'Open Access consists of providing online access to all available scientific information (articles, monographs, research data...) free of charge for the reader and under license so that it can be used and exploited by researchers, companies and citizens. The idea behind open access is that results and data used in publicly funded research should be available to everyone and have licenses that allow their reuse' (p. 4). The open access definition is made explicit in the Budapest Open Access Initiative (BOAI) (Open Society Institute (OSI), 2001), and in the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (Max Planck Gesellschaf, 2003).

[3] All of this integrates and transcends the principles of Open Access and Open Science applied to publicly funded studies, and is in line with the most relevant aspects of the institutional repositories evolution proposed by the Confederation of Open Access Repositories (COAR) (COAR, 2018), and also with the FAIR (Findable, Accessible, Interoperable and Reusable) principles, which are mandatory for the beneficiaries of the projects framed in the European programs Horizon 2020 and Horizon Europe (HE). Furthermore, the implementation of the RAM-ADP&RN-IR would be susceptible to adapting and developing the new standards established by the Open Access Infrastructure for Research in Europe (OpenAIRE) (OpenAIRE, 2018).

- Each AI processes input information by means of a 'transformer' model as a neural network[4], whose contextual machine learning is limited to considering the existing and validated information within the RAM-ADP&RN-IR, such as the original documentation from the architectural projects, the information provided by research agents validated by documentary centres and universities, and the information produced by generative computing from AIs validated by research agents, and in turn, by documentary centres and universities.

- Each AI generates, based on the input information and the specific requirement of a research agent, information by computation (or also named 'output information'), rationally explaining the relationship between the input and output information, arguing for validity, the invalidity and possible indeterminate validation of the output information, as well as showing the complete process of generating the output information, in line with the principles of transparency and understanding of generative computing of Explainable AI (Explainable Artificial Intelligence, also named 'XAI')[5]. Therefore, the AI neural networks considered here are also governed by the principles of XAI and are named XAI.

- Each XAI achieves its model, or training aimed to its specific function within the RAM-ADP&RN-IR, by means of the information provided by a research agent in the successive reviews implemented on the output information produced by the XAI considered.

- The set of XAI constitutes a network (or model, according to the technical terms) of XAI agents, which are consequently capable of communicating and interacting with each other when applying the RAM-ADP&RN-IR, and in turn, the information from the communications and interactions produced are equally explainable.

- The intercommunication information between XAI agents that alters the training model of an XAI must be reviewed and validated by a research agent, and subsequently, by the documentary centres, by the universities, and by the owner entity.

2.2. RN-IR: research network- institutional repository, database editable under permission, authorizable, perfectible, traceable and automatable by means of XAIs

The large amount and diversity of data that could predictably be part of the RN-IR, and the suitability of managing it in an efficient, selective, and comparative manner, would indicate the convenience of the introduction and processing of digital information being performed by means of a computer database that would interact with the XAIs accredited within this digital entity.

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[4] This automated contextual learning technology (machine learning) was publicised for the first time within the text 'Attention is all you need', presented in No. 30 of the publication *Advances in neural information processing systems*, in 2017; (Vaswani *et al*., 2017).

[5] Explainable Artificial Intelligence, or XAI, is an emerging AI model that is capable of explaining the algorithmic calculation process that has been applied to the input information, and, therefore, the relationship between it and the data results obtained by generative computing may be understood. Derived from this, XAI is shown as opposition to 'black box' AI models, generally neural networks, where such a relationship between input and output information is unknown, even for specialists in AI programming. The importance of using XAI lies in the iterative control on the information production and the errors made in generative computing, which allows, in this case, to maintain and optimise the rigor and traceability of the architectural information used within the RAM-ADP&RN-IR.

The types and levels of action permission may be, at least, the following ones:

a. Non-automated reading of content: registered user with a non-automated reader profile, under permission of the owning entity.

b. Automated reading and selection of content: accredited XAI registered with reader profile and automated input information selector, under owning entity permission.

c. Non-automated content editing: registered user with an accredited researcher or research group profile, under owning entity permission.

d. Automated content editing after training by researcher agents: registered user with accredited Explainable Artificial Intelligence application profile, under owning entity permission.

e. Non-automated content validation: registered user with a profile of an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

f. Automated content validation: registered user with a profile of an accredited institution, documentary center, university, researcher or research group, under owning entity permission.

g. Content management: registered user with owning entity profile.

h. Non-automated content assessment: registered user with an external consultant profile from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

i. Automated content assessment: registered user with an external consultant profile from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

j. Performance assessment of an accredited XIA: registered user with an external consultant profile from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

k. Performance assessment of an accredited XIA: registered user with an external consultant profile from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

l. Automated content management assessment: registered user with an external consultant profile from an accredited institution, documentary center, university, researcher or research group, under owning entity permission.

The types of both content status and content management incorporated within the RN-IR could initially present the following scheme:

1. Non-automated inserted content: by means of an accredited researcher or research group, under owning entity permission.

2. Automated inserted content: by means of an accredited XAI, under owning entity permission.

3. Non-automated content inserted and validated: by means of an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

4. Automated content inserted and validated: by means of an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

5. Inserted, validated, and publicised content (accessible for the non-automated reader profile, and for the automated reader and selector of input information): by means of the owning entity.

6. Inserted, validated, publicised and reviewed content: by means of an institution, documentary centre, university, researcher or accredited research group, under owning entity permission.

7. Reviewed and publicised content (accessible for the non-automated reader profile, and also for the automated reader and selector of input information): by means of the owning entity.

8. Non-automated content assessed: by means of an external consultant from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

9. Automated content assessed: by means of an external consultant from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

10. Non-automated content assessed and publicised (accessible for the non-automated reader profile, and also for the automated reader and selector of input information): by means of the owning entity.

11. Automated, assessed and publicised content (accessible for the non-automated reader profile, and also for the automated reader and selector of input information): by means of the owning entity.

12. Non-automated content management assessed: by means of an external consultant from an accredited institution, documentary centre, university, researcher or research group, under permission of the owning entity.

13. Automated content management assessed: by means of an external consultant from an accredited institution, documentary centre, university, researcher or research group, under owning entity permission.

14. Non-automated content management assessed and publicised (accessible for the non-automated reader profile, and also for the automated reader and selector of input information): by means of the owning entity.

15. Automated content management assessed and publicised (accessible for the non-automated reader profile, and also for the automated reader and selector of input information): by means of the owning entity.

Due to the potential synergies that could be developed between research agents, research centres and universities, the exigency to determine a specific date and to attribute specific authorship to the actions and the corresponding introduction of data in each of the constituent parameters of each of the phases of application of this methodology would become evident[6]. Derived from this, all actions performed by an XAI that have been validated by researchers, documentation centres and/or universities, would have the same consideration, so the research actions would be classifiable as 'non-automated', if its agent is a human being, or as 'automated', if they have been produced by an XAI. On the other side, the emergence of new documentary units, the uncertain development of the inquiry process, and the desirable subsequent intervention of the researcher as the initial author of an action and the corresponding introduction of metadata within the RN-IR, or that of other researchers that review, update, or improve said initial action along with the addition of metadata, would demonstrate the convenience of adding subsequent actions and incorporation of data and metadata, also identified by means of a specific authorship of execution and dating, which would make possible to know the actions history and the corresponding data and metadata introductions linked to that of their authors, for a specific parameter of the database[7]. Derived from the above, the information contained within the RN-IR, both non-automated and automated, would be traceable by means of the histories in which the origin of the digitised documentary units and the authorship and specific dates of the actions performed are defined within RN-IR, which would imply detailed knowledge of the research history of a specific architectural design process. Additionally, this quality would allow the RN-IR to undergo external quality controls that would imply its institutional accreditation, in which the information produced in a non-automated manner could be discriminated from that obtained by means of XAI generative computing.

2.3. Phase I: Digitisation, designation, documentary atomisation and semantic-parametric attribution

Phase I along the application of the RAM-ADP&RN-IR[8] is mainly characterised by the researcher's action of digitising and inserting the documentary units of a project within the RN-IR, as well as establishing a designation that allows the linking from these to the documentary centres that host them by means of the corresponding web links. Furthermore, this work would be externally recognised and validated by the documentary centres involved, which would certify the accuracy and quality of the digital information deposited within the RN-IR by a specific researcher at a given time.

Considering the above, the intervention of two types of XAI could be considered: the XAI for documentary atomisation (DA-XAI) and the XAI for semantic-parametric attribution (SPA-XAI), which would allow the three-dimensional and constructive digital modeling of an architectural project based on its documentary units.

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[6] Documentation digitisation, digitised documentation detailed cataloging, both organisation of architectural type and the design versions organisation adding their characteristic parameters and validation criteria, and finally, graphic synthesis.

[7] Likewise, it would be equally desirable for the actions of the rest of the agents involved along the systematic application of the RAM-ADP within the RN-IR to be subject to identical criteria.

[8] For a thorough reading, consult “6. Phase I: Digitization and Designation” (Mondéjar, 2023).

The DA-XAI would be in charge, under expressed request from a researcher, of reading a digitised documentary unit, for example, a plan or a sheet of text, and decomposing it into minimum units identifiable owning a graphic sense (point, line, and plane, mainly) or textual one (letters, symbols...), which would be assigned a code and would have no meaning. Subsequently, researcher's task would be to review and validate the minimum units offered by the DA-XAI of a documentary unit of the project, and to argue the invalidity of those that would not be useful for the architectural inquiry[9]. If this procedure is extended to a documentary units selection of the project performed by the researcher, the researcher's review and validation information could be considered as the training of the DA-XAI model, which, from this moment on, would have the capacity of being in charge of atomizing the rest of the documentary units of the project. Finally, the process iteration would allow the DA-XAI model improvement and the complete validation of the atomization by the researcher, and subsequently, by the documentary centres involved and by the owning entity.

Starting from the validated database of minimal meaningless units, the researcher would have the opportunity to select a documentary, graphic and/or textual unit, and assign a meaning and a series of parameters (dimensional, material and construction) to each one of the aforementioned minimal units of information empty of meaning to provide them with an architectural sense when applying the RAM-ADP&RN-IR. Likewise, the research agent would be in charge of associating minimal units with each other to assign them equally architectural meanings, and in this way, three-dimensional and constructive digital entities with architectural meaning could be created[10]. In this manner, the process of creating a three-dimensional digital architectural model would begin that would be associated with a documentary unit of the analysed project. If this process were applied to a documentary units selection performed by the researcher, both the researcher's meaning assignment and architectural parameter information could be considered the training of the SPA-XAI model. Next, the SPA-XAI would perform, under explicit request from a researcher, both a meaning automated and architectural parameters assignment to a selection of atomised documentary units. Based on the automated assignment, researcher's task would be to review and validate the semantic-parametric attributions offered by the SPA-XAI for the documentary units' selection that are analysed, and to argue the invalidity of those that would not be correct and useful for the architectural creative process research. Finally, the process iteration would allow the SPA-XAI model improvement, and also the complete validation of the semantic-parametric assignment and the three-dimensional architectural and construction models of the documentary units by the researcher, and subsequently, by the documentary centres involved and by the owning entity.

2.4. Fase II: Phase II: Detailed cataloging and documentary charts automation

Phase II along the application of the RAM-ADP&RN-IR[11] consists fundamentally of detailed cataloging that thoroughly analyses twenty-four fields of each of the documentary units of a

[9] In the case of an architectural plan in which there are imperfections onto the support material or within the graphic definition, they could be validated as units that would hereafter be meant as such, to differentiate them from units that have an architectural meaning attributed to them.

[10] For instance, a meaningless line on a ground floor plan would become a section line of a face (exterior or interior) of a wall at a certain topographic level, referring to the material or construction system that materialises the aforementioned wall. If the researcher associated the two lines that define the exterior face and the interior face of the considered wall, he would have the opportunity to create the digital three-dimensional entity of the wall with its topographic, dimensional, material and construction parameters.

[11] For a thorough reading, consult. '7. Phase II: Detailed cataloging' (Mondéjar, 2023).

project, the result of which is the corresponding documentary chart (or also, detailed cataloging chart/record) associated with each of the documentary units analysed[12]. In this case, the researcher would be the agent in charge of entering the information of the fields of each documentary record within the RN-IR, whose validation by the documentary centres and universities would recognise the researcher's investigation, and in turn, would certify the quality of this database for consultation from the documentary centres themselves and for accredited reference of academic research. Regarding the above, detailed cataloging would allow the substantiation of the decisions adopted along the following phases of the RAM-ADP&RN-IR, which would make it possible to link the creative process organisation to specific cataloged parameters of specific documentary units.

On the other side, the performance of the XAIs of Phase I on the digitised information of a project when applying the RAM-ADP&RN-IR as well as the Phase 2 characteristics, would allow considering the presence of the detailed cataloguing XAI (DC-XAI), aimed at the automation of the assignment of units of information with meaning and with specific architectural parameters (SPA-XAI) to the documentary cataloguing fields, and also, to the introduction of descriptive, analytical and/or interpretative information of the fields of each documentary record.

Similarly to what happened along Phase I, the researcher would be the agent in charge when entering the information corresponding to each field of the documentary record, taking as a reference the original digitised documentation and the semantic-parametric attribution of the XAI that has been validated, along the detailed cataloguing record of a documentary unit. The information input by the researcher would include the description, analysis and interpretation of the available information and the association of the semantic-parameterised information units (SPA-XAI) considered. If this process were applied to a documentary units selection performed by the researcher, the information within the fields of their documentary records could be considered as the training of the DC-XAI model. The DC-XAI would then, under explicit request from a researcher, performed an automated input of information into the fields of the detailed cataloguing records of a selection of documentary units. Hereafter the automated assignment, researcher's task would be to review and validate the information within the fields of the documentary records provided by the DC-XAI of the selection of documentary units under analysis, and to argue the invalidity of those that would not be correct and useful for the architectural creative process research. Finally, the process iteration would allow the DC-XAI model improvement, and the complete validation of the detailed cataloguing of the documentary units by the researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity[13].

[12] For a thorough reading of the detailed cataloging charts/records composition, consult the heading 'Catalogación pormenorizada: fichas documentales': (Mondéjar, 2017). These fields are the following ones for each documentary unit (DU): Document centre (DC), document block, DU, designation of the DC, DU with specific designation, group of DU with specific name, type of document, nature of the DU, number of pages, format in mm, DU material support, graphic technique on the format and material, DU title, explicit dating, authorship signature of the content and/or meaning of each DU, description of the DU content, DU interest for the inquiry, explicit or implicit graphic scale for each of the graphic contents defined on a DU, DU conservation status, character of original or copy of a DU, superimposed as stamps, processing signatures and clarifications made on a DU, observations, design version to which a DU belongs and characteristic parameters of said version, stratification of design versions on a DU, generic inter-document relationship, inter-document relationship of type of architectural parameter, and inter-document relationship of design version.

[13] The validation of at least the fields 'Design version' and 'Layering of design versions on the documentary unit' would imply the intervention of personnel specialised in the field of knowledge of 'Architectural Design', belonging to a higher education institution.

2.5. Phase III: Creative process organisation and automated architectural interpretation

Phase III along the application of the RAM-ADP&RN-IR[14] basically consists of the documentation organisation of an architectural project available within the RN-IR into groups of documentary units that express chronologically ordered design versions, by means of the corresponding design version records, according to the validation criteria of internal coherence, external coherence and contextual correspondence[15]. Furthermore, after the establishment of the design versions, Phase III defines groups of documentary units that show the evolution of architectural element types throughout the creative process, by means of the following architectural type charts/records[16]. In this case, the researcher would be the agent in charge for entering the information of the fields of each version chart within the RN-IR, whose validation by the documentary centres and universities would recognise the researcher's research, and in turn, would certify the quality of this organisation justified on the basis of the original documentation for the development of the researcher's inquiry (foci detection for architectural criticism, traceable and perfectible organization over time), for consultation of the documentary centres themselves and for accredited reference of academic research as a methodological and evaluation instrument of research production in the field of Architectural Projects.

On the other side, as specified within the analysis of the RAM-ADP&RN-IR application (Mondéjar, 2023), the information produced along Phase III is essentially interpretative although it uses descriptive information fields from the detailed cataloguing, since the documentary grouping criteria depend fundamentally on parametric characterisation, which consists of the specification of a specific series of parameters extracted from the fields of the documentary records, and which, as they are common to the documentary units considered for a version, characterise it among the rest of the project documentation and with respect to the rest of the design versions. Consequently, its validation criteria of internal coherence, external coherence and contextual correspondence can only be applied by a specialist in the area of knowledge of Architectural Projects. Therefore, the main validation of this phase, as well as that of the interpretative fields of the detailed cataloguing, should be performed by university staff or staff belonging to other bodies and institutions specialised in the aforementioned field of knowledge.

Similarly to what happened along Phase II, detailed cataloguing and automation of documentary charts/records, the researcher would be responsible for entering the

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[14] For a thorough reading, consult 'Phase III: Organization of the design process' (Mondéjar, 2023).

[15] The version charts/records are composed of general information, parametric characterisation, and parametric assignment. The general information of the version analysed describes its physical scope, the chronology, the name of the inquiry, the state of development of the design, the general proposal of the architectural model, the total number of documents, the list of primary documents, and the list of secondary documents. Next, a code is proposed for each characteristic parameter of the version considered, each of these is linked to a specific field of the documentary unit record of the detailed cataloguing, the content of the parameter is described, and the validation criteria of the estimated parameter are also provided: internal coherence, external coherence, and contextual correspondence. Finally, the documentary units integrated in the version are assigned to the specified characteristic parameters; 'Versiones de diseño: fichas y consideraciones terminológicas' (Mondéjar, 2017).

[16] Basically, type charts show the evolution of the same type of architectural element by establishing groupings of analogous documentary units - graphicly described using dihedral system (ground floor plan, main elevation plan, roof plan...), construction element (plan of the porch on the first floor, construction section plan of an opening on the facade, construction detail plan of the sill in the opening of the façade, construction plan of the seating furniture...), perspective view (overall perspective, conical perspective of the main access...)- throughout the different design versions already established; 'Integración documental: Versiones de diseño y tipo de elemento arquitectónico' (Mondéjar, 2017).

information associated with each field of each design version chart/record and of each architectural type chart/record, taking as a reference the original digitised documentation, the semantic-parametric attribution and the detailed cataloguing of the documentary units of the project under inquiry, which have been reviewed and validated within the RN-IR.

In essence, the documentary units grouping expressing a design version and performed by a researcher must evidence the presence of a specific and identifiable architectural model in a given location, and characterised dimensionally, materially and constructively in a specific manner, as contemplated within the RAM-ADP[17]. Well then, the SPA-XAI previous action has allowed each documentary unit to be associated with a three-dimensional virtual model corresponding to the portion of the project they represent. Consequently, the joint composition of the three-dimensional virtual models associated with each of the documentary units that compose a design version would make it possible to approximate the construction and visualisation of the architectural virtual model of the version considered.

Indeed, both drawing of the documentary units corresponding to graphic representations and perspectives, the textual dimensioning values that direct and give dimension to them, the textual information of reports, specifications, measurements and budgets[18], and the information external to the project, but closely related to it[19], constitute a set of information that would be difficult to express total accuracy and coherence along the task of composing a three-dimensional virtual architectural model based on the exclusive SPA-XAI application. Derived from it, the researcher should introduce rectification and homogenisation criteria within the configuration of this virtual model hosted within the RN-IR and associated to a specific design version[20]. If this process were applied to a selection of design versions performed by the researcher, the information from the fields of their version and architectural element type records, as well as from the rectifications and homogenisations produced to constitute the three-dimensional architectural models of the selected versions could be considered as the training of the two XAI models estimated for Phase III: the XAI for version parameterisation (VP-XAI) and the XAI for version architectural modelling (VAM-XAI).

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[17] Fundamentally, two design versions differ from each other in terms of the architectural model that characterises them, which, although they may share an appreciable number of architectural elements, do not show two identical spatial configurations in terms of location, dimensions, materials and construction elements. In the case of two architectural models with a significant level of coincidence, in which the essence and main characteristics of the models were fundamentally identical, it would be appropriate to assign them to a single version with different solutions in certain locations of the project, which, in any case, would have a marginal condition within the spatial proposal that synthesises both models.

[18] Information that is processed taking into account the internal consistency validation criterion when parameterising the design version under analysis.

[19] Information that is processed taking into account the contextual correspondence validation criterion when parameterising the design version under analysis.

[20] This performance implies the use of the expert understanding of the researcher in Architectural Projects, who, depending on the available documentation and its content, should decide which specific aspects of the project could be prioritised over the rest and provide reasons to justify them. For instance, the drawings of directions and dimensions in freehand architectural plans usually involve a certain degree of imprecision within the graphic representation, which the dimensioning and associated textual values present within these plans or in other documents (such as memory document, technical specifications, measurements and budget) would be responsible for objectively aiming to the imprecisions and incoherencies, regardless of the dimensional tolerances considered when using the instruments of measurement and representation and when taking the corresponding data in the physical field of action of the project analysed.

The VP-XAI would accomplish, under expressed request of a researcher, an automated input of information within the fields of the version chart of a selection of documentary units attributed to a specific design version, performed by the VP-XAI itself. Along this task, VP-XAI should detect a series of characteristic parameters, extracted from the original digitised documentation, from the information produced along the previous phases and from that generated by the researcher as training for the VP-XAI, which would allow an automated and argued grouping of documentary units for the constitution of a specific design version. Likewise, the VP-XAI would be responsible for providing, for each characteristic parameter of the version obtained, the information that would justify the validity of the criteria of internal coherence, external coherence and contextual correspondence. Based on the automated action, researcher's task would be to review and validate the information within the fields of the version records offered by the VP-XAI of the documentary units selection assigned to the versions considered, and to argue the invalidity of those that would not be correct and useful for the architectural creative process research. Finally, the process iteration would allow the VP-XAI model improvement, and also the complete validation of the definition and organisation of the design versions by the researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity.

The VAM-XAI would fulfill, under explicit request of a researcher, the rectifications and homogenisations of the virtual three-dimensional models associated with the documentary units that VP-XAI has grouped to constitute a specific design version that has been validated within the RN-IR, aiming to virtually building the three-dimensional architectural model of the considered version. Along this task, VAM-XAI should establish a series of priorities when realising the joint and complete harmonisation of the virtual models of each documentary unit, extracted from the original digitised documentation, the information generated along the previous phases and the produced by the researcher as VAM-XAI training, which would make possible the constitution of a complete virtual architectural model representative of a design version, capable of linking its elements to the original documentation of the project, and also, its visualisation by means of any system of representation, including immersive Virtual Reality experiences.

After defining the design versions and the version records that characterise them, the researcher would be in charge of grouping a selection of the project's documentary units, each of them already assigned to a specific design version, by type architectural element and establishing the corresponding chart. If this process were applied to a selection of architectural element types accomplished by the researcher, the information within the fields of their architectural element type records could be considered as the XAI model training estimated for Phase III: the XAI of typological association (TA-XAI).

The TA-XAI would perform, under explicit request of a researcher, a grouping of documentary units associated with a type of architectural element and would be responsible for completing the fields of the corresponding architectural type chart. Along this task and for each architectural type, TA-XAI should identify a specific type, based on the original digitised documentation, the information produced along the previous phases and the information generated by the researcher as TA-XAI model training, that would allow an automated and reasoned association of documentary units for the type of architectural element considered. As a consequence of the fact that each of the documentary units that are part of an architectural type grouping have been previously assigned to a specific design version, the aforementioned grouping would express an ordered sequence in time of the type of architectural element considered, and also, the external coherence of the entire creative process applied to the aforementioned element. Hereafter the automated action, researcher's task would be to review and validate the information within the fields of the

type records generated by the TA-XAI of the selection of documentary units assigned to the architectural types considered, and to argue the invalidity of those that would not be correct and useful for the architectural creative process research. In the end, the process iteration would allow the TA-XAI model refinement, and also, the complete validation of the architectural type charts, and also, the transversal validation of the design process by the researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity.

2.6. Phase IV: Synthetic and automated virtual architectural modelling

Phase IV along the application of the RAM-ADP&RN-IR[21] basically consists of the graphic reconstruction of a design process portion that is not present within the original project documentation, or of the design process as a whole, by synthesising the available documentation content, based on the information and architectural knowledge created along the previous phases of the RAM-ADP&RN-IR application, which would provide a more synthetic and transmissible comprehensive vision of the creative process. Likewise, this phase would be subject to the same validation conditions as Phase III, since the graphic performance nature would be basically interpretative, as both the objective graphic information and that extracted from deductions from the RAM-ADP application would be framed within a specific version. The potential for use by documentary centres, researchers and universities would be similar to that described along Phase III for the same reasons specified along this one.

Essentially, Phase IV would allow to graphically represent part of an architectural model of a design version, or the model as a whole, which could not be evidenced due to the lack of information presented by the project's documentary units, but which can be deduced from them and/or from the information contained within documentary units external to the project, but closely related to it.

After the XAIs performance along the previous phases, the virtual architectural models originated along Phase I by means of the DA-XAI and PSA-XAI intervention, and that have been harmonised along Phase III by means of the VAM-XAI accomplishment, constitute the virtual architectural modelling information that expresses the explicit content of the documentary units of the project, and it is therefore, the basic source of information that the researcher can use to propose a partial or complete reconstruction of incomplete or missing architectural models of one or more design versions.

Thus, after the design versions specification and the virtual architectural models that characterise them, the researcher would be responsible for completing and/or creating an architectural model of the project, by means of the creation of virtual three-dimensional entities that own architectural meaning, parameterised similarly to the PSA-XAI operation manner and argued by means of their relationship with specific fields of the detailed cataloguing of the documentary units, of the parametric characterisation of the versions, or of their linkage with information external to the project, but closely related to it. In any case, the inclusion of partial modelling of a version would have as a spatial reference that one of the virtual architectural model of the version considered, and as a result of these actions, a synthetic virtual architectural model would be obtained, as a result of the consideration of the explicit information of the documentary units of the project and of the information deduced from these and from external information, but closely linked to the design process. If this process were applied to a selection of virtual architectural models performed by the

[21] For a thorough reading, consult '9. Phase IV: Graphic Synthesis' (Mondéjar, 2023).

researcher, the synthetic modelling information incorporated, and the arguments used could be considered as the XAI model training estimated for Phase IV: the XAI of synthetic virtual architectural modelling (SVAM-XAI)[22].

The SVAM-XAI would fulfill, under express request from a researcher, a first introduction of the incomplete virtual architectural model of the version considered, as a copy of the one existing within the RN-IR, and now qualified as the basis of the synthetic virtual architectural model (or also, basis of the synthetic model), on which the SVAM-XAI would perform the introduction of synthetic three-dimensional virtual entities (or also, synthetic entities) owning architectural meaning and the arguments of their connections with the information present within the documentary units of the project and those external to the project but closely linked to it, completing the synthetic virtual architectural model up to the level at which the internal and external information substantiates it.

Along this task and for each synthetic model base, SVAM-XAI would identify synthetic entities that would complete the aforementioned base, based on the original digitised documentation, the information produced along the previous phases and the information generated by the researcher as SVAM-XAI training, which would allow an automated and reasoned association of the synthetic entities with the previously mentioned information internal and external to the project. As a consequence of this, a new type of virtual entity would be generated within the RN-IR: the synthetic virtual architectural model (or also, synthetic model) associated with a design version, composed of the base of the synthetic model, the synthetic entities provided by the SVAM-XAI, and by the arguments that would justify the choice and positional, dimensional, material and constructive configuration of the aforementioned entities.

After the automated perform, researcher's task would be to review and validate the information of the synthetic entities and their coordination with the base of the synthetic model to which they are referenced, with the rest of the design versions of the creative process, and he would also be in charge of arguing the invalidity of the information that would not be correct and useful for the architectural creative process research. Finally, the process iteration would allow the SVAM-XAI model improvement, and also the complete validation of the synthetic models by the researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity.

2.7. Phase V: Researches assessment; updates, interactions between phases and automated coordination

As it is known, the inquiry process presents an uncertain development, since, although the information offered by the documentary units of a project is objective in nature, the creative process organization necessarily incorporates an interpretive factor that depends on personal vision of the researcher. Furthermore, the emergence of new information, either from documentary units of the project or from information external to the project but closely related to it, could significantly influence the approaches and results of the research accomplished. Adding to the previous, the complete validation of the design process of a

[22] Given the synthetic nature of the information generated along Phase IV, which considers the information present within the documentary units and that contained within external documentary units but closely related to it, and that, based on both, the researcher generates a virtual architectural modeling not present within the documentary units of the project, it would be recommended that the introduction of the three-dimensional virtual entities and the argumentation of their connection with the aforementioned information internal and external to the project, accomplished by the researcher, be developed by means of an XAI differentiated from the rest of those housed within the RN-IR: the XAI for synthetic virtual architectural modeling (SVAM-XAI).

project is not completed until the fields of the inquiry are equally complete and there are no inconsistencies between any of the phases of the RAM-ADP. It implies that the interpretative fields of the documentary charts/records could not be validated until all the design versions are ordered, and also that the intervention of new research agents or the emergence of new documentary units internal or external to the project could condition the final validation of the creative process.

Regarding the above, RAM-ADP&RN-IR application already foresees that the introduction of information within its virtual environment is dated and a specific authorship is assigned, so this inquiry methodology within the RN-IR is capable to adapt to the changing conditions of research without altering its approach, characteristics, or functionalities.

Well then, RN-IR environment including the intervention of the group of XAIs considered would allow automating the updates and interactions between phases already present along the RAM-ADP&RN-IR application similarly to that envisaged for the specific functions of each XAI hosted within RN-IR. This automated perform, not initially envisaged within the RAM-ADP&RN-IR, could be considered as Phase V along the automated virtual application of this methodology.

Indeed, given the existence of an update and/or interaction between phases that could alter the organization of the creative process accomplished by a specific researcher (researcher 1), said researcher would be in charge of reviewing whether the information incorporation within the RN-IR performed by another research agent (researcher 2) would affect their ordering of the design process. If affected, likewise as on previous occasions, researcher 1 would be in charge of executing the corresponding modifications within the RN-IR and within each of the XAI involved, arguing them, so that the variations produced would be linked to the new documentary units, internal or external to the project, as well as the new interpretations introduced by researcher 2, regarding the creative process analysis from researcher 1[23]. If this process were applied to a selection of updates and interactions between phases fulfilled by the different researchers, the updated information and/or interaction between phases incorporated and the arguments used could be considered as the XAI model training for Phase V: the XAI for automated coordination (AC-XAI), which would adopt the role of an automated researcher, but also reviewed and validated by a human researcher.

The AC-XAI should be able to communicate and interact with the rest of the XAIs within this virtual environment as an agent, as previously explained within section 2.2., and would perform, under express request of a researcher, an update and/or interaction of phases after the detection of new information to be incorporated and validated within the RN-IR, and would argue the proposals for information modifications within this virtual environment. Along this task and for each proposal to incorporate new information by a researcher, the AC-XAI should have to communicate with the rest of the XAIs, based on the information already existing within the RN-IR, including that generated by various researchers as the set

[23] For their part, researcher 2 should consider the information existing within the RN-IR at the time of starting their intervention, which would have to heed the information already inserted corresponding to the organisation of researcher 1's creative process. In the case of acceptance of researcher 1's information, researcher 2 would argue it by referring to the information used by researcher 1, which, anyway, would evidence the authorship (researcher 1) and the date of validation within the RN-IR. Otherwise, researcher 2 would argue the information they intends to validate within the RN-IR, explaining the reasons why researcher 1's argumentation for the same information is not considered valid. Furthermore, researcher 2 could propose to introduce a different information to that validated for researcher 1, but complementary to it, so that researcher 2's argumentation would explain the reasons for the complementarity of both information, which, in any case, should have the approval of researcher 1 for the validation of researcher 2's information, regardless of the non-researcher validating agents that would provide it with full validity within the RN-IR.

of XAIs model training, to assess the compatibility, incompatibility and/or complementarity of the new information regarding that already existing within the RN-IR, and propose the arguments corresponding to the meaning of the aforementioned assessment. As a consequence, AC-XAI automated performance would play the role of an automated researcher agent, which would give authorship and date to the new design process organisation after the appearance of the novel information. Based on the automated accomplishment, human researcher task would be to review and validate the new proposal for organising the creative process and the arguments that support it, generated by the AC-XAI, and to argue the invalidity of the one that would not be correct and useful for research into the architectural design process.

Finally, the process iteration would allow the AC-XAI model improvement, and also, the complete and transversal validation of the creative process updated organisation by the human researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity.

2.8. Phase VI: Research optimisation and automated generation of creative process organisations

Analogously to what happened along Phase V, the use of an XAI as an automated research agent, but also reviewed and validated by a human researcher, would allow the proposal of organising the creative process of an architectural project as an alternative to another one or several already existing within the RN-IR. This automated accomplishment, not initially contemplated within the RAM-ADP&RN-IR, could be considered Phase VI along the automated virtual application of this methodology.

Thus, the set of the creative process organisations that has been performed on an architectural project, characterised by the information and arguments that justify them, in which a series of human researchers have intervened, the corresponding XAIs along the first four phases, and those of the AC-XAI as an automated researcher agent for the fifth one, could be considered as the XAI model training for Phase VI: the XAI for automated generation (AG-XAI), which would pay the role of an automated researcher, but reviewed and validated equally by a human researcher.

The AG-XAI would be able to communicate and interact with the rest of the XAIs within this virtual environment as an agent, as previously explained within section 2.2., and would accomplish, under expressed request of a researcher, a proposal of the design process ordering to incorporate and validate within the virtual environment, arguing it as applied along the RAM-ADP&RN-IR. Along this task and for each proposal for a new automated creative process organisation, AG-XAI should intercommunicate with the rest of the XAIs, based on the information already existing within the RN-IR, including that generated by various researchers as training of the XAIs set, to assess the compatibility, incompatibility and/or complementarity of the new organization regarding that already existing within the RN-IR, and propose the arguments corresponding to the meaning of the aforementioned assessment. As a consequence, the automated performance of the AG-XAI would play the role of an automated research agent, which would grant authorship and date to the creative process new organisation. Based on the automated accomplishment, the human researcher task would be to review and validate the new proposal for organising the creative process and the arguments that support it, generated by the AG-XAI, and to argue the invalidity of the one that would not be correct and useful for research into the architectural design process. Finally, the process iteration would allow the AG-XAI model improvement, and also the complete and transversal validation of the updated organisation of the creative

process by the human researcher, and subsequently, by the documentary centres, by the universities, and by the owning entity.

3. Outcomes

The paramount outcome of the research is the architectural design process organisation of a project that transcends the RAM-ADP&RN-IR application by means of the performance of the XAIs hosted within this virtual environment and controlled by research agents, documentary centres, universities and the owning entity, capable of strengthening the perfectibility and traceability of the research, and also, of facilitating researchers the application of this methodology by means of the multiple tasks automation without losing human control of research arguments. Likewise, the aforementioned organisation incorporates the presence of virtual models of each of the design versions, which would also facilitate research, and even dissemination at the institutional and user level, by means of advanced digital viewing and editing devices, such as Virtual and Augmented Reality. Due to the above, it may be considered the constitution of the Reconstruction and Assessment Methodology of the Architectural Design Process (RAM-ADP), integrated into the digital entity of a mixed nature and open access, the Research Network-Institutional Repository (RN-IR), and the controlled intervention of Explainable Artificial Intelligence (XAI) technologies: RAM-ADP&RN-IR&XAI, or also, XAIRM.

4. Discussion

The research of the XAIRM application on the creative process is able to substantially improve the researcher's work, as it allows them to automate extensive and lengthy analyses of a large number of documentary units that must subsequently be reviewed and validated, and therefore facilitates the research progress. As a consequence, the XAIRM instrumental value is considerably increased, as it allows equally increase the amount and quality of architectural criticism to be based on optimised analyses of creative processes which are funded on documentation available. On the other side, the XAIRM implementation requires the existence of a very important technical XAI management and IR-RN maintenance team, which may condition the XAIRM viability.

Furthermore, the consideration of the XAIRM evidences, not only the RAM-ADP&RN-IR structural optimisation, but also a more transcendent perspective on the use of AI, which, in addition to facilitating work performed by human beings, allows for solidity in rigor and traceability along the processing of information and knowledge during research, as XAIs technologies are currently accomplishing in various fields. Regarding this, both its extensive implementation in the rest of the human activity areas and the 'black box' AIs role should become an ethical order question that would demands to be rethink and regulated for the benefit of real human progress.

5. Conclusions

In summary, the XAIRM application represents a transcendental evolution regarding the RAM-ADP&RN-IR virtual constitution, which in turn already implied the digital systematisation integrating an open science sense of the Methodology of Reconstruction and Evaluation of the Architectural Design Process, or RAM-ADP. Fundamentally, the XAIRM would maintain and strengthen the researcher leadership along the inquiry process, whose information and arguments introduction within the RN-IN would train a set of explainable artificial intelligence (XAI) models as agents, which subsequently would accomplish part of

the research tasks, finally reviewed by the researcher before validation within the virtual environment by documentary centres, universities, and the owning entity. Furthermore, although the XAIs specialisation within the RN-IR would peak its maximum exponent with the consideration of the AG-XAI for automated generation, which would play a role of automated researcher agent, capable of ordering the design process as a whole, the control of the information established within the RN-IR, the request for information, the output information and its arguments, would correspond to the human researcher and the rest of the institutional agents, such as documentary centres, universities and the owning entity. This would guarantee the rigor and traceability of the research performed by the XAIRM, and its potential assessment by external agents.

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