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Abstract.
This is prospect research on digital preservation at the crossroads of blockchain and artificial intelligence with a double aim: first, fulfil a vision of self-preserving digital objects and contribute with a dare step towards the long-term digital preservation, and second, open an area of research that is the preservation of value once we are witnessing the dawn of the internet of value enabled by the advent of blockchain and other distributed ledger technologies.

Keywords: Agents, Digital Preservation, Blockchain, DLT, Virtual Currencies.

1 Introduction

For keeping Digital Objects (DOs) genuine and usable for a long time, there is a new need of **digital preservation** (DP) for the prevention or curation of their obsolescence regardless of how they are stored (whether in cloud, local, or distributed and accessible through ledgers) with a series of operations: migration of formats (Rabinovici, 2011), curation whenever errors occur, metadata to understand their context, errors in the early DP strategy, and so on and forth. Unfortunately, these operations derive in costs in maintaining the DP services that are growing in a way to risk turning up unaffordable. A lack of DP resources causes losses in DO usability and integrity and, certainly a loss of value. My proposition was to redistribute the costs of DP so that everyone contributes to the DP of whatever DO of personal, business, administrative, cultural, historical, scientific, educational, artistic, economic, or any other reasons for **value**.

DP strategies so far have been centralised: national archives and libraries play a central role, a central view, where open source solutions with archivists, professionals or amateurs are dominating the DP landscape. An example of a centralised system with crowd contributions was the FP7 DURAFILE project (http://www.durafile.eu - *Innovative Digital Preservation using Social Search in Agent Environments*), where I introduced social search and agent technologies to develop collaboratively preservation plans for DOs (Trias et al., 2013a) (Trias et al., 2013b). However, **nearly no attempts to fully decentralise and distribute the DP and its costs have been developed** and none of them has been successful yet. A first approach was Nelson et al. (2001) and years later our we worked out our own approach in MIDPOINT project (http://easy4.udg.edu/midpoint - *Nuevos enfoques de preservación digital con mejor gestión de costes que garantizan su sostenibilidad*), with the birth of cost-aware digital

object (CADO). Other examples in the literature were *buckets* to make archives smarter as (Nelson et al., 2001) proposed or *agents* that become aware of obsolescent formats and seek suggestions from other agents (Pellegrino, 2014). Those years, we settled the foundations of an Object Centric View (OCV) of the DP versus the prevailing central view that intelligent agents fit well as a solution.

Meanwhile, the field of **cloud storage has been fast moving towards distributing the storage of digital content by means of DLTs**: Siacoin (Vorick et al., 2014), Filecoin.io (Protocol Labs. 2017), and the protocols IPFS (Benet, 2014) or Akasha.world are examples of fully distributed, peer to peer storage and provide benefits in robustness and in cost reduction. As DP is built-up on top of *storage*, a distributed cloud storage will help addressing several of the said DP issues like usability, integrity, and cost. These early developments of cloud storage with costs reduction and enhanced scalability opened my eyes: there is chance to apply DLT to DP to save similar magnitude of costs reduction. Moreover, it is worth exploring how our OCV might also adopt the DLT to better deal with ***value* when DO are indeed digital assets**.

Thus it is worth revisiting DP with my **OCV with a new background on DLT** to fulfil my vision of DP developed by intelligent, autonomous agents as social (peer to peer) duty (de la Rosa et al., 2011) living on a ledger, aiming at reducing costs by several orders of magnitude (de la Rosa 2015) while keeping intact usability and integrity of DOs and their value: The OCV of DP by the adoption of Intelligent Agents paradigm adapted to the DLTs is a paradigmatic view of distributing DP that we expect will impact not only in scalable cost for obsolescence management but in **diminishing the potential value losses of digital assets after being exchanged many times.**

2 Initial Hypothesis and General Objectives Pursued

My first hypothesis is that the OCV of DP developed as smart contracts under **the intelligent agent paradigm can be empowered with DLT to deliver the less costly DP solutions**, aiming at a linear growth of their costs through time instead of an exponential one.

My second hypothesis uses an analogy of the DO obsolescence through time and DO value depletion through a succession of change of hands. In DP, while time is passing, DOs suffer from a sequence of migrations or technology innovations. This degradation process of the DO integrity and other properties happens in parallel to the DO value loss after a sequence of ownerships and licenses: it will be object of Value Preservation (VP). Thus, the second hypothesis is that **DLT/AI based OCV of DP will properly preserve the value of digital assets.**

It is an unchartered territory: *value preservation* (*VP*). We explore how value is preserved in Intellectual Property (IP) preservation, notably in Open Innovation (OI) and industrial secrets contained in 3D objects model designs (3DDO). Then, we *revisit* the Cost Aware Digital Object (CADO) research and develop the proper intelligence to deal with Long Term Digital Preservation (LTDP) by distributing the preservation logic, efforts, and cost, which means bringing together the benefits of DP together with those of intellectual property preservation (IPP), and develop them on DLT.

On one hand, I seek for DOs that autonomously connect to preservation services. There are two topics that need to be researched in this area:

First topic, there is need to find out whether preservation is provided as a service (e.g. by currently existing DP solutions providers) that can be called remotely through oracles or as smart contracts (SC). In a first case, further R+D is necessary for preservation services being called through oracles, DP solution-providers that offer closed solutions so that third parties call to their services remotely. In a second case, one step further is that preservation services would be implemented as SC as well. This would require an important change in DP solution providers, since anyone able to provide preservation services would be able to create a SC and each node of the DLT would, thus, execute the DP services when the SC are called.

Second topic, it is a key research topic to tackle how to enable that a SC works autonomously. Current DLTs and SC solutions do not enable SC to self-run themselves periodically or after a specific amount of time and they need to rely on external services (either human or software agents) that take charge of calling the SC when needed. Those external calling entities are also responsible for the provision of the funds to run the SC. There is a need to change the paradigm to enable the development of fully autonomous DO relying on SCs. To do so, we bet for creating a fork of one of the open-source existing SC platforms like Ethereum and extending their implementation to support such a kind of operation.

On the other hand, there is further research need in how to improve trust in collaborative environments though IP protection of the DOs that contain an asset to be shared. Here the key aspects to be tackled include ownership, which is solved in the state of the art, but also ownership transfer and inheritance, which need to be further researched. Any DO can be subject to transactions according to its value that might affect the value itself, either monetary losses or misuse losses because of the death of the owner, for example. Any DO needs to include mechanisms to foresee that it has been sold or its rights have been transferred to someone else, because the owner decided so or because a mechanism as SC has initiated the transfer after the owner's death.

Other IP related issues include licensing, access control, and reporting. Here the main research challenge relies on autonomously transferring any resources collected by the DO to the owner's balance. Additional research challenges involve the distribution of encryption keys to access content, which cannot be encoded directly into SC, since SC are publicly accessible. Thus, as already mentioned, some mechanisms are needed to enable a fully autonomous operation of the SC in combination with the presence of specific trusted software components in the device of the licensee.

Finally, we foresee the deployment of a token, the Preserva (PRE). *Preservas* are supplied for the tasks of IP preservation (IPP), curation, ingest, checking acknowledgements, mining, and validation of their IP transfer, management, and more. They are created as the friction (fees) of the IPP services over DOs that are registered/entered on the ledger. PRE are paid as the fee for the uploads, transfers, and more, of the DOs, so that they are next allocated to the acknowledged sources as if they were DO (i.e., they were registered, i.e. uploaded). PRE are also paid for checking license, terms of agreement, implemented as SC and the validation of ordinary transactions, or for keeping the

DO in the ledger activities. The PRE are created (supplied) for the fees of IP and DO preservation and/or storage DOs despite of any virtual currency might be provisioned for budgeting the costs of DO IPP. That is why the PRE is a utility token, as it can be used for fees or for the IPP.

3 Agents for Managing Digital Preservation, its Cost, and The Value of Digital Assets

Said that, let's talk further of the agent approach for costs and value. **First**, reducing the magnitude of LTDP has immediate reduction of cost yet the cost might still be exponentially growing unless we adopt the OCV of DP: We have argued in section 2 that the reduction is achievable by converting the DOs into **smart DOs, intelligent agents that selfpreserve under a budget in virtual currency for DP and VP**. That's it, our works in 2014-15 (Olvera and de la Rosa, 2014, 2015a, 2015b, 2015c) showed that the smart DO are able to manage their DP costs after we introduced self-preservation skills and goals in their intelligence: we **reduced the exponential growth of cost towards into a flatter one**. This is key for the LTDP. We called them CADO (Cost Aware Digital Object) or SPDO (Self-Preserving Digital Objects). In all, CADO was a bottom-up approach of cost management in DP using e-auctions, contrary to the prevailing top-down approach of the state of the art.

First point, algorithms to be researched and re-implemented under SCs as intelligent agents linked to DO are the electronic auctions (e-auctions) which are still a novel approach to managing costs in DP. It is such a kind of solution that takes advantage of the said OCV developed by means of CADO whereby the DOs manage their self-preservation by maximizing the chances of avoiding obsolescence but at a minimum cost. To accomplish this, we assign a budget that the DOs manage to secure the supply of preservation services at a given cost. Several strategies apply, such as maximal preservation service at all costs or burn low even if the preservation outcome is not perfect. We explore optimizing the budget of SPDO through micro-negotiations of DOs and services, expecting accurate balance of costs and quality of preservation. Specifically, in negotiation, we explored price-based algorithms, like the e-auctions with combinatorial and multi-unit auctions (Olvera et al., 2015a). We compared the expected lifetime of DOs under those 2 e-auction algorithms to decide under what conditions they apply and deliver good results. These results will be revisited in the DLT implementations. We defined then a virtual currency called PRESERVA (₱/PRE) to extemporize and universalize the price assignment of the LTDP services' costs so that we use the same prices now and in the future regardless of the monetary paradigm, as well as provide a budget for CADO in a transparent, easy, and general way. **1₱ is the cost of preserving a DO for 100 years**. In our experiments, we used the m₱ (miliPRE) as the DLT token. Thus, prior to a full DLT implementation, simulation experiments delivered interesting results like the following (baseline in blue, multiunit in red, and combinatorial in green for the y-axis, and the x-axis are the number of technological changes that are multiple of 5 years each, thus 20 changes means 100 years). Next experiments to confirm theses result will be done in emulation first in a testnet and then in the open network with a DLT:

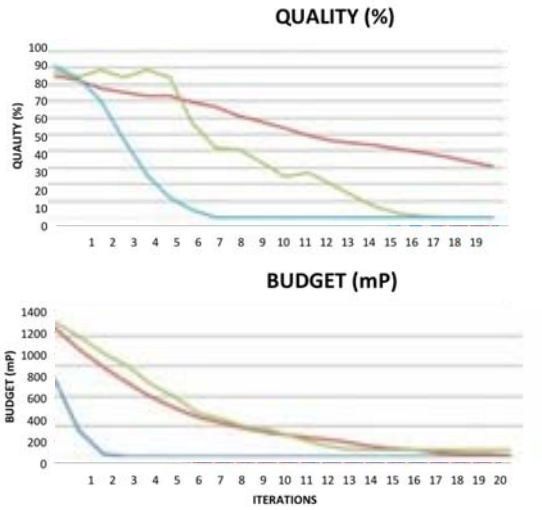

Fig. 1. Quality in % and Budget in mPRE of DOs through time, of three e-auctions algorithms

Second point, with the advent of DLTs, the CADO can become a reality as long as we achieve DLTs with **SCs** to support smart and autonomous DOs. I plan to revisit the CADO state of the art with the DLT approach and go far beyond the self-preserving properties through their cost management and introduce other aspects into the study where preservation is also of prominent importance such as the **preservation of value VP**, which is today ill-defined.

We define *value preservation* as "dealing with (explicit) ownership and rights management along with digital preservation of data which, regardless of formats and platforms, is being transferred and processed among entities across public and private bodies". **The preservation of value** means keeping **integrity, genuinity, and usability** of the value related to the DO, for a long term, **across exchanges**. Data, the DOs, turn into digital assets which value, whatever will be, is preserved.

Value is then **an agreement of one or several parties over the digital assets they are using by licensing**. It could be of personal, intellectual, historical, artistic, societal, industrial, or economic dimension of value. I'm talking about handling the VP and not the *value creation*, thus we will just take a theoretical baseline value that will be kept as strong as initially was along the chain of licensing.

Third and last point, being said that one of the dimensions for granting value to DOs is Intellectual Property (IP) and acknowledging there is a growing need to preserve IP (de la Rosa et al. 2017) as means to preserve the value of DOs, for which ownership (including its transfer and inheritance), licensing, access control, and reporting are relevant aspects that need to be handled. Otherwise, usable and well-preserved DOs from the DP perspective that are bundled to wrong or unauthorised owners **derives into a complete loss of value**, whether for which owners are no longer licensed, accessed or traced.

4 Applicability of the Research

I plan to develop use cases of the *preservation of IP value*, on the domain of online platforms for OI and on industrial trade secrets over industrial designs contained in 3D digital objects (3DDO). **OI and industrial designs contained in 3D objects are two application domains** where IP is of special relevance: The leaks of IP by inappropriately using 3D industrial design is estimated to be causing 200 billion dollar losses only in the US manufacturing industry in favour of Asian countries in counterfeit goods, pirate software, and theft of trade secrets. The fact is the digitization of know-how and online collaboration is making IP leaks much easier than ever. In this line, the lack of effective IP rights management has been identified as one of the main barriers for collaboration to be effective. In the survey (Bikfalvi et al., 2016), the factors acting as hinderers to OI mentioned that beyond the main concern relative to resources –an issue inherent to their SME structural configuration, and their difficulty in finding trustable/reputable partners, **IP issues represent a major concern** (Chesbrough and Ghafele, 2014). Being OI recently redefined by (Chesbrough, and Bogers, 2014) as the "use of purposive inflows and outflows of knowledge to accelerate internal innovation", it assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they seek to improve their performance; this notion of OI is largely based on **transferring knowledge**, expertise, and resources from one company or research institution to another (Van de Vrande et al., 2009), with the risks of **losing value** because of an authorised or inappropriate usages of the digital asset. This is our approach to the preservation of value.

Online OI platforms are territories of huge big data effect, gamification approaches, AI in the automation of ideation and project support services, as well as rewarding schemes with reputation and virtual money, or novel IP management, which need to be researched, developed, and tested in the online OI (Bogers at al., 2017). I focus the application cases on **IP value preservation (IPP)** that might play an important role in the development of OI platforms. For the IPP, as I stated in (de la Rosa et al., 2016) DLTs are expected to open up a range of possibilities as well as challenges. Some of these are already underway, while others may take considerable time due to e.g. regulatory constraints.

There are several IP related applications where DLTs can play an important role (de la Rosa et al., 2017b) that need to be mentioned: *Timestamping, proof of existence or notarization* relies on the use of cryptographic hashes of IP assets to provide proofs of existence. As well, with DLTs, a new wave of *decentralized IP registries* and services have arisen. They can range from just covering authorship recognition, to more sophisticated services enabling access to content, licensing and other features. DLTs and timestamping services can be used together to create an auditable trail of content ownership from creation to the transfer of rights and beyond, while *access control* relies on giving and controlling access to some content to predefined users. It might be used in combination with licensing or NDAs. DLTs enable the implementation of access control mechanisms through the combined use of SCs, record keeping solutions and encryption mechanisms. Examples are Po.et, Creativechain.org, Ascribe.io, and IPSeeds.net. *Licensing* determines the rights and conditions under which someone can make use or access some content or work belonging to the copyright owner. Decentralized licensing relies on SCs. Examples are Creativechain.org as well as the said Ascribe.io and Po.et. Finally, Non-Disclosure Agreements (NDA) are used to establish a trusted environment for a background knowledge exchange each party is willing to communicate to others and each party recognizes and proves it happened by stamping a signa-

ture on. Some initiatives relying on DLTs include IPSeeds.net and Bernstein.io. About *record keeping*, since DLTs are not suitable to keep large amounts of data, alternative mechanisms have been conceived to link files from the DLT itself through the use of hashes and addresses: For example, the IPFS is a P2P protocol under DLT. Finally, thanks to DLTs, it is possible to **design cryptocurrencies to reward or promote behaviours** among the community of knowledge users. Currency designers can determine when new currency is issued and to whom. Existing cases include said Po.et, Creativechain.org, and Witcoin.io

Thus**, through DLTs, I can extend CADO to embrace the DO VP**. If it is put into practice, there will be no need to have centralised systems to manage the VP, and the DOs themselves would be able to act as autonomous objects in the search of their LTDP, keeping their value intact through time.

Our research will contribute to a renewed approach of LTDP, that with the focus on IPP we expect to not only reshape the state of the art of DP, DLT, and intelligent agents.

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