Toward a Unified Art ID: Reviewing International Standards for Art Identification and Provenance Management in the New Digital Age

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Abstract

As our world becomes more digitised, so must our methods in categorizing the data. Digital media and content creation have always suffered from the threat of misinformation and a lack of transparency. Furthermore, AI has risen with meteoric speed, outstripping our abilities to carefully extricate it from human-made media, further exacerbating the issue of data privacy and misrepresentation. Several standards have been created to help organizations verify digital media and establish its provenance, but a comprehensive comparison of all the standards has yet to be conducted. This paper provides a comparative analysis of six major initiatives: Coalition for Content Provenance and Authenticity (C2PA), Art Identification Standard (AIS), International Image Interoperability Framework (IIIF), Linked Open Data (LOD), Linked.art and Digital Object Identification (DOI). We examine their approaches to content authentication, metadata interoperability, stakeholder communities, provenance tracking, and anti-piracy measures. Through analyzing the similarities and differences between these standards, we highlight their strengths and gaps. Our findings underscore the need for a more universal framework that integrates the best practices of current standards. We conclude by proposing considerations toward a unified art identification system that can be easily applied to art images worldwide, ensuring trust and transparency in the global digital art ecosystem.

Keywords: art ID, blockchain, decentralized identifiers, provenance, C2PA

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Introduction

As the Internet grows and becomes an increasing presence in all aspects of our lives, ensuring authenticity of an image has become a more prominent issue. The Internet is a wonderful place where data can become interconnected across institutions; research avenues are opening with ease that could not have happened before. However, with the rise of openness and rapid dissemination of images and information, we have entered a new age of misinformation, forgery, and misattribution. Traditional experts of provenance and authenticity, experts, appraisers, and museums must adapt to keep pace with both the rise of misinformation and accessibility. Provenance, the documented history of an artwork's ownership and origin, is crucial in both the art world and as a datapoint in research. Furthermore, Cultural Heritage Institutions hold a wealth of data about "images and their metadata, artworks and their metadata, and all related information, such as artist details, dates, conservation data, provenance data, and more" (Dressen, 2025). With these unique influences coming together, the need for reliable identification for artworks (both physical and digital) has become the mission of many institutions.

Internationally, multiple standards and initiatives have been proposed over the years to solve the question of how to accurately display content provenance, first due to the sheer amount of data that institutions hold and are willing to share due to the gradual shift to adopt open data but then due to the recent advent of powerful AI image generation. Each standard addresses a piece of the problem, from assigning unique IDs and embedding metadata into digital files to creating frameworks for sharing art information across institutions. However, these efforts have largely developed in parallel. Six of these prominent standards that we will be examining are:

1. **Art Identification Standard (AIS):** a governance framework that highlights the problems of incompatibility across systems, information loss and distortion, asymmetric information and diversity of views (*Home | Art Identification Standard*, n.d.). Founded in June 2019, it aims to be a standard such as "ISBN, DOI and ORCID" (*FAQ | Art Identification Standard*, n.d.).
2. **Digital Object Identifier (DOI):** A unique string assigned to an object, physical, digital, or abstract, used predominantly in academia. DOI's website states that it solves a common problem "keeping track of things. Things can be matter, material, content, or activities" (*Home | DOI Foundation*, n.d.). The standard was approved in November 2010 and published in 2012, it is a well-established system that has shown to work well in certain industries and was conceived as early as 1997 at the Frankfurt Book fair after recognizing the trend towards digital convergence and multimedia availability (*DOI Handbook*, 2023).
3. **Coalition for Content Provenance and Authenticity (C2PA):** An open technical standard for "publishers, creators and consumers to establish the origin and edits of digital content" (*Content Credentials*, n.d.). It aims to ensure content is adaptable with standards as the digital ecosystem evolves. Established from the concern surrounding deepfakes, voice cloning, and synthetic media. It looks into building trust in what is displayed online.
4. **International Image Interoperability Framework (IIIF):** A set of open standards that gives its audience access to many images and audio/visual resources that used to exist in silos, access that used to be restricted to locally-built applications (*International Image Interoperability Framework*, n.d.). Focusing on interoperability, any IIIF-compliant image server can work with any IIIF viewer. Allowing users to "publish once, reuse often" and "remix content."

5. **Linked Open Data (LOD):** An approach rather than a single standard, LOD refers to the American Art Collaborative, a consortium of 14 art museums committed to establishing a "critical mass of LOD on the semantic web." Funded from 2014–2017, it aims to "exponentially enhance access, linking and sharing of information about American art in a way that transcends what is currently possible with structured data" (*American Art Collaborative Linked Open Data Initiative | Smithsonian American Art Museum*, n.d.).
6. **Linked.Art:** A community working to create a model based on Linked Open Usable Data (LOUD) to describe cultural heritage, with a focus on artwork (*Linked Art - Linked Art*, n.d.). Version 1.0 was released in February 2025. It aims to define a metadata application profile and the technical means to interact with it using an API.

Each of these standards is working towards reliable authenticity in its specified field, taking different approaches. The remainder of this paper is organized by thematic aspects: blockchain usage, metadata frameworks, metadata fields, and community. By comparing their strengths and weaknesses, we can understand where they converge and identify opportunities for creating a more universal art ID system that builds on their successes.

It is worthwhile to also give credit to Carnegie Museum of Art (CMOA) which had created and funded the development of Art Tracks in 2013–2015. This project aimed to convert textual provenance records into structured, machine-readable data—extending the AAM standard into a strict superset that supports JSON, Linked Open Data, and RDF—thereby enabling sophisticated queries, visualizations, and cross-institutional storytelling (Newbury, 2017). The official project can be found at https://www.museumprovenance.org/ and the open source library has been shared at Github https://github.com/arttracks/provenance-interactive.

Blockchain Technology in Art Identification Standards

Bureacă and Aciobăniței (2024) define three technical mechanisms to protect content authenticity: applying digital signatures to verify the signer's identity, using watermarks as unique identifiers, and storing identifiers in the blockchain and distributed ledger technology (DLT) systems, which have strong potential to improve trust in the storage of online data. Historically, most of our data has been stored in centralized databases that the public deemed to be controlled by trustworthy entities (Cheney et al., 2009). However, digital data and document metadata are constantly being modified as they are moved around the internet without central control, undermining the credibility of any online data (Lynch, 2001). Blockchain and DLT systems offer potential to solve this problem by storing data as a chain of immutable transactions that have been confirmed and validated in a decentralized system. The World Wide Web Consortium (W3C) has earlier defined the use of decentralized identity (World Wide Web Consortium (2022) which also suggested the use of blockchain and DLT technologies. These digital infrastructures can create and manage digital originals with fixed content, a uniquely identified owner, and a confirmed time of creation. To register a piece of literary art or artwork to the blockchain, the system creates a cryptographic envelope around the original content and the owner's private key and adds a timestamp. Although multiple copies of the data can be created, the owner retains the rights to the content. If the owner transfers the rights to another person, an amendment cryptographic envelope containing the original cryptographic envelope and the transfer information is registered to the blockchain, therefore preserving provenance (Batista et al., 2021). Chun (2023) has also suggested that the Art ID Standard (AIS) (wwe.artidstandard.org) organization which was initiated in Europe with

an international membership base which is currently under development also proposed the use of blockchain technologies specifically using decentralized identity.

Multiple frameworks utilizing blockchain have been developed to protect data authenticity. One example is to combine blockchain with an off-chain storage solution called a data lake, removing the need to trust a third party for data storage and maintenance (Vishwa & Hussain, 2018). Eliminating third parties simplifies intermediary costs and lowers the risk of data being modified without the owner's consent. Another framework leverages blockchain, crowd wisdom, and AI to create a decentralized platform for fact-checking and trust assessment (Buțincu & Alexandrescu, 2023). It uses web crawlers to fetch online news into the blockchain and a combination of federated AI modules and human validators to analyze the content. This system also uses an off-chain storage component to store a bundle of text and media for each processed news item. Bureacă and Aciobănițe (2024) claim that their framework offers more features than other existing frameworks: it identifies fake information, handles more than one category of media, and follows the C2PA standard, which improves the potential for the framework to be adopted. The above frameworks are just a few examples of blockchain solutions proposed to improve data security and authenticity. The applications of these frameworks in enhancing data provenance demonstrate the benefits of using blockchain in protecting artists' ownership of their work and implementing art identification standards. In regards to the six art identification standards being examined in this paper, only AIS explicitly uses blockchain, although C2PA is also compatible with blockchain. More details regarding each standards applications in blockchain are provided below.

AIS: AIS assigns each artwork a decentralized identifier (DID) that is distributed on the blockchain (Magnin et al., 2023). This standard also contains multiple metadata fields pertaining to blockchain, which will be explained in more detail in the metadata frameworks section.

C2PA: Although the C2PA standard does not require the use of blockchain, it is still compatible with blockchain systems, as evidenced in the framework proposed above by Bureacă and Aciobănițe (2024). In their framework, information can be verified by analyzing the blockchain with the resource identifier in the C2PA metadata within the CCM. Therefore, the authors claim that "every C2PA compliant tool can be used to read and extract provenance information about a registered asset." C2PA also includes metadata fields that allow W3C Verifiable Credentials to be embedded in a manifest (*Content Credentials : C2PA Technical Specification :: C2PA Specifications*, n.d.).

DOI: The DOI system is an important tool for managing digital objects by resolving frequently changing URLs into unique and permanent identifiers to help locate online resources or research papers. The DOI system does not use blockchain, and is, in fact, centralized; therefore each publisher pays a fee to an official registration agency to register a domain name. However, DOI digital objects are still vulnerable to modifications or copying. Although the DOI system itself does not use blockchain, there may be ways to improve this system. For example, Rong et al. propose to replace the traditional DOI system with decentralized identities (DID) for decentralized distributed digital objects; their system also uses NFT-like schema and smart contracts (2022).

IIIF/LOD/Linked.Art: Neither LOD, IIIF, or Linked.Art use blockchain technology, but rather they focus on more centralized systems for managing art collections. LUX, a knowledge-graph discovery system, is an example of a platform that uses the Linked Open Data standards

IIIF and Linked.Art to house over 41 million records related to art, natural history, archival, conservation, and bibliographic collections (Sanderson, 2024). Sanderson explains that LUX's "overall architecture for acquiring, processing and loading data was informed by the need for a single system to manage the information" (2024).

We conclude that AIS and C2PA are most compatible with blockchain technology and decentralized systems, while DOI, IIIF, LOD, and Linked.Art standards employ centralized data storage systems.

MetaData Frameworks

One core question when creating a standard is "how do we get the information across in an accurate and efficient way?" Many museums hold extensive information on artworks and are willing to share it with the public, but have no way of categorizing it in a way that is interoperable and readable to many who wish to query the dataset. As E.Fink states, "today's documents about artifacts are being chronicled in a variety of machine-readable formats that do not allow us to easily make connections across multiple databases and museums websites at once" (2018) and as M. Magnin, executive chair of AIS, writes, echoing the one of the first pillars of EU digital transformation "data is an essential resource for economic growth" (2022). Data is crucial to the growth of both worlds of collecting art from financial to research, the standards explored in this paper all try to tackle and find a way to sort and order metadata attached to artworks.

AIS formats their data by supplying an identifier distributed on the blockchain, hence the name DID (Decentralised + Identifier) (*Standard | Art Identification Standard*, n.d.). It bases itself on W3C terminology and technology, using a DID controller; entities that have the capability to make changes to a DID document. The DID will point to where the metadata can be found, whether it can be accessed at a cost or freely (Magnin, 2022). Contributors to the AIS also must conform to the AIS DID protocol, which "contains a set of formally-defined metadata fields used to document an object for the purposes of identifying that object and recording information relevant to the creation of the associated AIS DID" (Magnin et al., 2023). The aim of this framework is interoperability, so that different platforms such as galleries, auction houses and artists themselves can interoperate using this common ID. Artists can retain a self-sovereign control over their data without relying on centralized authorities. The metadata itself is less extensive than other standards, focusing on four sections: Aggregation, Object, Entity Resolution and DID management. It also, interestingly, adds a tiering system designed to reflect the confidence one has that the AIS DID connects and is related to a specific object. The ID is a tool to facilitate verification not an outright stamp of approval.

DOI, much like AIS, has a single identifier, but which points to the object rather than a set of metadata. However, the DOI system does require a core set of metadata to be stored in the DOI registry. The metadata model was based on the INDECS (interoperability of data in e-commerce systems) interoperable metadata framework (*DOI Handbook*, 2023). The use of the metadata is to "enrich" the service provided to users as the users can search for a DOI name using metadata. Like AIS, the metadata framework follows strict rules so that DOI can achieve interoperability and the automated integration of metadata. One such rule is that for every entity identified with a DOI name must have a minimum set of mandatory metadata (DOI Kernel), to make sure that every entity within the system is identifiable. The limitation behind this, however, is that it must be applicable to every single entity within the system, not just artworks. Thus, the metadata is broad with no data specific to art. Of course, additional information can

be declared but it is not mandatory. DOI shows us how to establish a reliable system with a persistent identifier, even when information surrounding it may change, such as ownership or location.

Other standards, such as IIIF, have extensive metadata frameworks, due to their nature as primary research viewers. IIIF Presentation API specifies a JSON-LD based format for image metadata and sequence structure, called a Manifest. The manifest holds information on a particular piece, the title and other descriptive information (Appleby et al., 2012). The metadata itself is an ordered list of human-readable label and value entries; with entries that could be information about the creation of the object, physical description, and ownership information. IIIF allows limited metadata for the creation of the manifests but allows creators to add more if they wanted to. The API further builds on interoperability by allowing users to have external links within the metadata, with the appropriate label and value to describe the relationship. The linking of data allows for a deeper understanding of the information held by IIIF, which allows for a richer researching experience, to further this, the API also allows internal links such as "partOf" that allows users to navigate collections with ease. AAC is an example of museums adopting IIIF for the express work of contrasting works of art and as a key function of conducting research (Fink, 2018).

Linked.art is perhaps the most extensive of all the standards we will look at, as it has a focus towards artworks and museum-oriented activities. They state that their scope "is to define the semantic description of cultural heritage items, and the important surrounding contextual information such as people, places, concepts and events." Despite the large amount of data, they aim to make sure that they are interoperable and easy to use. Like IIIF, Linked.art also utilizes JSON-LD documents and the CIDOC-CRM model with GETTY vocabularies (*Home | CIDOC CRM*, n.d.). The metadata allows objects and people to be easily searchable and easily linked to multiple different themes. For example, two museums publish data using Linked.art, a researcher could query all objects that a certain artist created, this level of semantic interoperability is essentially data integration by design. The trade-off is complexity. Linked.art requires sophisticated mapping of legacy data into the model and a commitment to maintain those URIs and references. As shown by the Leeds library when it decided to categorize its data through Linked.art, "it became very apparent in discussions with peer institutions such as The Getty Trust that implementing a data model is no mean feat" (Abel, 2024). However, the benefits of implementing are greater, a step towards open, interconnected data.

C2PA has a different approach to their metadata framework, as it is not so much linked to the other frameworks due to its broader spectrum of content; social media posts and digital art being created at this moment. Its aim is to standardize provenance metadata attached to a media file and to document its journey through the internet. The C2PA specification defines their metadata through fields such as content's creator, edit history, software used and timestamps and is signed by a specific signer enabling cryptographic validation and attribution of the data (*Content Credentials : C2PA Technical Specification :: C2PA Specifications*, n.d.). C2PA is concerned with the way the metadata files are treated by consumers, with many social media platforms stripping metadata for privacy and size reasons (Steidl, 2016). Thus, alongside their files, C2PA users must have a compliant C2PA reader to ensure validation.

In summary, the two main concerns with the metadata frameworks are interoperability and validation of IIIF and Linked.art strive to make information exchange across institutions as seamless and effective as possible. DOI and AIS establish a single reference identifier which people can refer to but requires additional metadata to allow them to be searchable in a

database. C2PA refines their focus on metadata to just provenance logs that can be shared between content editing and publishing platforms. Only AIS has proposed to adopt the use of blockchain technologies particularly following the concept of the W3C Decentralized Identity methods. The following Table 1 depicts the metadata being used for identifying an artistic object.

Table 1

Comparison of Metadata Fields Across Five Digital Media Standards

Metadata Category	AIS	DOI	C2PA	IIIF	Linked.art
Title/Identifier	title objectURI imageURI referenceNumber	DOI name referentIdentifier(s)	dc: identifier xmp:Identifier Iptc4xmpExt:DigImageGUID	id label	id identified_by
Creators	creators creatorsURI	principalAgent	author	-	produced_by carried_out_by destroyed_by removed_by modified_by encountered_by used_for
Creation Date	creationDate	dateOfBirthOrFormation	dc:date xmp:CreateDate	navDate	timespan
Size/Format	measurements objectType materialFormat	structuralType mode character	dc:format dc:type Iptc4xmpExt:DigitalSourceType Iptc4xmpExt:Genre Iptc4xmpExt:MaxAvailHeight Iptc4xmpExt:MaxAvailWidth	type format height width duration	classified_as dimension
Location	currentLocation	associatedTerritory	Iptc4xmpExt:LocationCreated	-	current_location current_permanent_location took_place_at
Rights/ Registration	rights rightsURI	registrationAuthorityCode issueDate issueNumber	Iptc4xmpExt:RegistryId	rights requiredStatement.label.Attribution provider	current_owner current_custodian current_permanent_custodian
Blockchain/DID	blockchainTokenID blockchainInitialTXNHasRecord blockchainInitialChain blockchainMetadataURL blockchainSmartContract blockchainViewOnChain dIDCreator dIDCreatorURI dIDCreationDate dIDVersion dIDDefinition dIDTier dIDCreatorAuthority	-	credential	-	-
Groups/ Related Items	aggregationType, aggregationConnectedItems	linkedCreation linkedParty associatedTerritory	dc:relation	seeAlso partOf	member_of
Other	isShownAt distinguishingFeatures subjectMatter tagIDCode tagIDType tagIDDef tagEncoding tagEncodingType tagEncodingDef	primaryReferentType referentType dateOfDeathOrDissolution	**Refer to C2PA Technical Standards for Full List of Metadata Fields*	**Refer to IIIF API for Full List of Metadata Fields*	**Refer to Linked Art API for Full List of Metadata Fields*

Note.

- AIS classifies its metadata into four tiers, with Tier 1 requiring the least amount of metadata fields and Tier 4 requiring the most (Magnin et al., 2023).
- C2PA metadata assertions support numerous schemas–for brevity, only some of the relevant fields from the schemas XMP Basic, XMP Media Management, Dublin Core (DC), and IPTC Extension have

been included (*Content Credentials : C2PA Technical Specification :: C2PA Specifications*, n.d.). The required elements for a C2PA manifest are a label that ends in ".metadata" and a single JSON content type box with the @context property and the JSON-LD serialization of at least one metadata value. This is specified in more detail on the C2PA technical standards documentation.

- The DOI Metadata Kernel listed above includes the minimum required metadata fields (*DOI Handbook*, 2023). Additional metadata fields can be declared if they comply with existing metadata schemas. More details can be found on the DOI Handbook.
- IIIF has a field titled "metadata" that can include any metadata the user would like, but these entries are intended for presentation only (Appleby et al., 2012). IIIF also requires different metadata fields depending on the type of object or property, which is explained in detail on the IIIF API.
- The Linked.art metadata included above is from the Linked.art API for physical objects, which includes artwork (*Linked Art API: Physical Object Representation - Linked Art*, n.d.).
- The most relevant metadata fields have been included above, but the full list of the metadata fields for C2PA, IIIF, and Linked.art can be found on their respective websites.

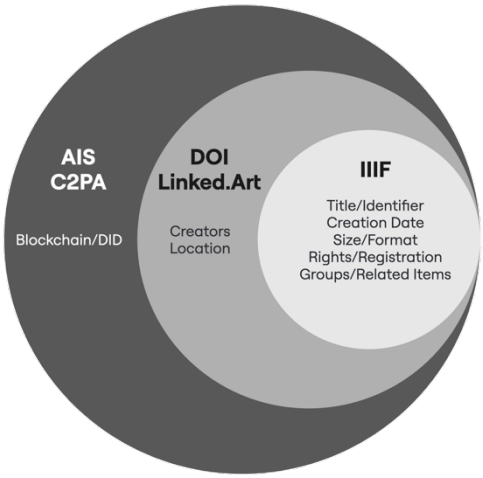
Communities and Their Objectives

The very purpose of art is about communicating, conveying a message, it then makes sense that "preserving and providing access to cultural heritage resources relies on collaborative, community-driven initiatives" (Raemy, 2023). The standards discussed in this paper all have a community around them, ranging from DOI and C2PA whose community consist of those who use the protocols and help uphold them; to IIIF and Linked.art whose community is much more open to individuals who wish to educate and help build the protocols and standards. However, these different communities have been the cornerstone of the drive and development; focusing on two areas: outreach and education.

IIIF and Linked.art have big community drives for outreach, IIIF making it clear within their website that they meet regularly and are open to everyone (*IIIF Community and Technical Specification Groups*, n.d.). These programs are for anyone around the world and while most of the IIIF participants are from the United States, Europe or the UK; the participation of other countries across the globe has been noted (Raemy, 2023). showing the effort to create a global network of collaboration. As Demlas-Glass and Sanderson (2020) state, "The mission of cultural heritage institutions is to share knowledge effectively to further scholarship and it is important that they participate in the development of the framework that disseminates their knowledge in the semantic web." While museums and other art institutions like universities strive to find the resources to follow any one standard such that the dissemination and provenance management could be managed at scale as handlers. It is the existing art community ecosystem that really lack the resources to maintain a common standard. AIS's mission is meant to deliver this change by forming as a non-profit organization to promote the adoption of Art ID Standard.

In summary, the communities surrounding each standard and their aims largely coalesce into two main pillars: Outreach and Education. Teaching cultural institutions about these standards increases the likelihood that they too will upload their data onto the web in a way that's interoperable and easily queried for the future (Fink, 2018).

Figure 1
Comparison of Metadata Fields Across Five Digital Media Standards



A New Novel Concept of an Art ID Registry Using DID:ART and DID.ART

The authors proposed the use of W3C DID:ART and a domain name DID.ART as a framework to implement a blockchain-based system infrastructure to allow digital platform providers to apply for an unique Art ID from the server endpoints that are agnostic of any blockchain network but yet follow the metadata framework proposed by AIS and one which can also implement the C2PA protocols suggested by the Content Provenance and Authenticity Coalition as well as the metadata framework required by the Chinese National standard of the Digital Copyrights Identifiers 3.0 (DCI 3.0). DCI 3.0 is currently operated by the subsidiary company of Alibaba called Ant Financial using AntChain as the blockchain. Such novel Art ID metadata framework proposed by the authors has not been achieved before as there is currently a limitation for the Chinese's very owned DCI 3.0 standard (Chun, *personal communications,* 2025) due to the need to authenticate real persons or an entity's real ownership.

Conclusion

In this era of digitized data, the rise of generative AI and the increasing use of open data sharing present significant new challenges for the art world. There is a pressing need for flexible, comprehensive, and secure data frameworks capable of adapting to an evolving digital landscape to ensure proper art provenance and management. Harnessing the combined strengths of approaches such as C2PA's provenance data, IIIF viewers, and AIS blockchain solutions suggests that a unified and interoperable system is both feasible and desirable. However, successful unification requires recognizing the unique features of each technology, enabling the framework not only to integrate diverse standards but also to support specialized use cases for museums, art galleries, insurance companies, historians, researchers, auction houses, art funds, and collectors. The DID:ART and DID.ART framework proposal aims to fulfill this promise by providing a foundation robust enough to thrive amid the rapid changes of the AI era, and trustworthy enough to safeguard and connect diverse types of media creations and artworks for the future. Future work will involve further development of the system architecture and detailed specification studies.

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