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Foreword

Recently, Non-Fungible Tokens (NFTs) have garnered considerable interest and debate. Several digital assets that NFTs point to are either in existing JPEG formats or can be represented in current and emerging formats under development by the JPEG Committee. Additionally, various trust and security concerns have been raised about NFTs and the digital assets on which they rely. To better understand user requirements for media formats, the JPEG Committee launched the JPEG NFT exploration initiative. The scope of JPEG NFT is the creation of effective specifications that support a wide range of applications relying on NFTs applied to media assets. The standard shall be secure, trustworthy and environmentally aware, allowing for an interoperable ecosystem relying on NFT within a single application or across applications. The committee strives to engage stakeholders from diverse backgrounds, including technical, legal, artistic, and end-user, to establish use cases and requirements.

Introduction

The JPEG Committee recognized the potential benefits of integrating photography with blockchain technology early on, since February 2018.^{1*} Given that the majority of digital assets in NFTs are in the form of one or more JPEG 1 files, it is a reasonable next step for the JPEG Committee to investigate opportunities to contribute to the standardization of NFTs. Moreover, these assets may be represented in other JPEG formats, such as JPEG 2000, JPEG XT, JPEG XR, or JPEG XL. In addition, digital arts can use emerging and potential future formats such as JPEG AI or even JPEG DNA. Furthermore, several digital arts are dynamic and can be short videos, animated content or longer videos. Digital art can also be potentially represented in various existing and emerging formats in JPEG that can include animations or short videos, such as motion JPEG 2000, motion JPEG XR, motion JPEG XL, JPEG XS, or in HTJ2K. Last but not least, a growing number of minted digital assets are in the form of immersive, and they can be represented using 360 contents as standardized in JPEG Systems and using JPEG Pleno format.

Given that the majority of digital assets in NFTs are in the form of contents (e.g., images, animations, and 3D models) that are easily represented in JPEG formats, it is a reasonable next step for the JPEG Committee to investigate opportunities to contribute to the standardization of NFTs.

JPEG's past and present efforts have been heavily reliant on NFT-based media assets. These include the JPEG Universal Metadata Box Format (JUMBF), which enables the embedding and referencing of any metadata in any JPEG image; standardization efforts on JPEG Privacy and Security, which aim to provide methods for protecting metadata or (parts of) the image content; and ongoing work on JPEG Fake Media, which is focused on the exploration of functions related to the creation of a standard that will facilitate secure and reliable annotation of media assets to combat illegal activities.

The present and near-term goals of JPEG's NFT investigation are to identify numerous application cases in which JPEG may contribute best practices and standards to resolving the techno-legal issues raised by NFTs in this study. To accomplish this goal, stakeholders from academia, industry, and end-user communities participated in several JPEG-organised workshops. The presentations and video recording of these workshops are available on <https://jpeg.org/jpegnft/documentation.html>.

^{1*} https://jpeg.org/items/20180213_press.html

Use Cases and Requirements for JPEG NFT

1 Scope

The scope of JPEG NFT is the creation of effective specifications to support a wide range of applications relying on NFTs applied to media assets. The standard shall be secure, trustworthy and environmentally aware, allowing for an interoperable ecosystem relying on NFTs across independent applications.

2 Terms and Definitions

To ensure a correct understanding of the descriptions in this document, here we define terms and concepts as they are used in the context of our work (in alphabetical order).

Actor: A human or non-human (hardware or software) that is participating in the media ecosystem. For example: a camera (capture device), generation or editing software, cloud service or the person using such tools.

Authentic media asset: media asset that is verifiable and/or trustworthy.

Blockchain: The blockchain system is one type of distributed ledger architecture. It can be public, private, or hybrid. Bitcoin (BTC) and Ethereum (ETH) are the most well-known public blockchains. Ripple (XRP) and Hyperledger are two popular types of private blockchains.

Distributed ledger: A distributed ledger is a database that spans many physical locations. A peer-to-peer network and consensus techniques are necessary to ensure that replication between nodes occurs. As a result, no central administrator is required to operate a distributed ledger. Consider a distributed ledger as a database distributed among several computers (nodes) connected via a peer-to-peer network. Each node autonomously duplicates and saves an identical copy of the ledger and updates it.

Digital asset: (see Media asset) include images, videos, audio or text. In the context of this document we mainly focus on images, however, other media types are not necessarily excluded from the scope.

Digital master: master media asset as intended by its creator.

GLAM institutions: Galleries, Libraries, Archives and Museums.

Identifier: an identifier uniquely refers to an asset, actor or associated rights.

IPR: Intellectual Property Rights are the rights given to actors over their creative work.

Ledger: A ledger is a book of accounts that contains the records of transactions. Each account contains three columns: a starting balance, a column for recording transactions as debit or credit, and an ending balance.

Media asset: digital assets including images, videos, audio or text. In the context of this document we mainly focus on images, however, other media types are not necessarily excluded from the scope.

Media asset content: the portion of a media asset that represents the actual content, such as the pixel data of an image, along with any additional technical metadata required to understand or render the content (e.g., a colour profile or encoding parameters).

Media asset metadata: the portion of a media asset that represents non-technical information about the media asset or its content, such as location, creator, annotations or IPR information.

Media asset origin: the actor that created the media asset.

Media asset provenance: a set of information about a media asset including the trail of modifications starting from an actor, for example, the media asset origin.

Media asset source: media asset produced by a device or method without any modifications.

Modified media asset: media asset that has been changed.

Manipulated media asset: media asset that has been changed with the intention to induce misinterpretation.

Media asset integrity: lack of corruption of a media asset.

Micro-licensing: micro-licensing is a legal phrase to describe the difference between a standard licence and a limited licence in terms of time, purpose, channels, territories, etc.

Minter: actor who publishes an NFT.

Non-fungible token (NFT): An NFT is a unique data record containing a verifiable reference to an asset. The record is stored on a ledger in the form of metadata and conditions of the transaction. The ledger could be distributed or centralized and the conditions of the transaction may be implemented as a smart contract.²

Phygital: a portmanteau of physical and digital, referring to the blending of the two experiences.

Registration: the process of declaration and storage information (e.g. media asset, metadata or provenance) about a media asset, separate from the media asset itself.

Registrar: an actor that performs a registration.

Searchability: the ability to find related media assets or NFTs based on an asset's identifier, portions of the asset's metadata, or content similarity.

Signing: a process that establishes the relation between an actor and a media asset in a tamper-evident manner.

Signer: an actor who digitally signs a media asset.

Tokenization: Tokenization is the process of putting an asset's ownership rights into a digital token that can be stored on a distributed ledger.

Trustworthy: able to be relied on as being what it is asserted to be.

Verifiable: able to be checked.

3 Use Cases

Numerous technical components, such as blockchain and smart contracts, are required for effective implementations of NFTs. Without the need for a centralized trusted institution, today, blockchain is the primary mechanism for securely storing information about an NFT's transfer record.

Numerous applications have already benefited from the special properties of NFTs, including physical, digital, and phygital assets, while others have been predicted but not thoroughly explored. Among the non-exhaustive list of such use cases are the following:

- Copyright declaration
- Licensing of media assets
- Trading of artworks
- Collectible media assets
- Gaming
- Ticketing
- Sharing media assets on social media
- Academic certification

² Source: NIST-IR 8301Section 6.3, Tokenizing Uniquely Identifiable Things and Supply Chains.

3.1 Copyright declaration

Multiple blockchain configurations are being explored in the copyright domain. If tokens represent rights, and wallet holders represent rightsholders, blockchains may host public copyright registries, which can record in a transparent manner the ownership, distribution, use, and remuneration of works.

For example, an open rights data exchange³ can store on a blockchain a token that binds immutably the identifier of a content with the authentication of a declarer, records the timestamp of the declaration and, optionally, the smart contract address that facilitated the transaction and an IPFS address of public metadata. One of this public metadata is in turn the permissioned address of a private store of confidential metadata.

3.2 Licensing of media assets

This subsection presents perspectives on using NFTs to enable automated rule-based licensing from a prospective open rights data exchange.

The lack of reliable, exhaustive, and current rights management information, combined with slow and expensive manual licensing procedures, prevents press publishers from taking full advantage of the neighbouring right granted by Article 15 of the European directive on copyright⁴.

Similarly, it prevents a multitude of contributors to educational content to be correctly remunerated in a sector where specific, dynamic assemblages of material are very difficult to trace.

Similarly, many copyright agreements for text, audio, and video clips include specific durations. For example, a commercial may have exclusive access to a song for a limited duration. After the time expires, they may not use the song in their advertisements. This is one reason why you usually do not hear two different commercials at the same time that use the same song. Only one has the exclusive rights to use the song for advertisements during the specified duration.

Furthermore, rental agreements, such as hotels, restaurants, and car rental services, issue temporary ownership based on non-negotiable licences.

Sample solutions include an open rights data exchange that would allow rights holders to declare their works and other related subject matters, as well as rights management information followed by automated rule-based licensing that could result from smart contracts or compiled expert systems.

3.3 Trading of artworks

Digital artwork is perhaps the most prevalent application for NFTs at the moment. Each day, artists and producers add their works of art to the blockchain as NFTs and sell them to interested buyers via a bid or at a predetermined price on the primary market. The blockchain maintains a record of each transfer, with the possibility of allowing for the payment of royalties to the original creator at each subsequent transfer on the secondary market.

In addition to enabling artists, NFTs can enable galleries, libraries, archives, and museums (GLAM) to raise funds by selling ownership of digital copies of their collections. As with real-world limited editions, where each piece is signed and numbered, the potential for NFTs to generate significant revenue for artists and museums has attracted the attention of many underfunded cultural institutions. For example, a digital copy of

³ For open rights data framework, see for instance DisTRi, a Distributed Trusted Rights Framework: https://www.academia.edu/44646056/DisTRi_a_Distributed_Trusted_Rights_Framework_for_Digital_Content

⁴ Article 15 of the European directive on copyright grants press publishers based in the EU the right to collect income from information society service providers who utilise their publications online; see Directive (EU) 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market and amending Directives 96/9/EC and 2001/29/EC (O.J. L 130, 17 May 2019, p. 118).

Michelangelo's Doni Tondo was the first to be sold as an NFT for \$170,000 by Uffizi Gallery,⁵ while the Hermitage Museum has revealed plans to sell NFTs for works by Da Vinci and Van Gogh.⁶

However, there are risks to be considered, in particular in relation to the rights of the sold assets. For example, the NFT art collective Global Art Museum (GAM) advertised for sale NFTs of Vermeer and Seurat masterpieces on the OpenSea marketplace, pledging to share earnings with the institutions that own the paintings. These NFTs were created using OpenGLAM.⁷ Legally, GAM did not violate copyright laws because images made available through OpenGLAM may be reused without restriction. However, GAM did create misleading impressions that it was in some type of relationship with the different institutions by branding its NFT collections after them (e.g., "The Rijksmuseum Collection") and proposing profit-sharing with rightful owners of the masterpieces. After the Rijksmuseum announced that it was not collaborating with GAM,⁸ the latter was compelled to remove all of its NFTs and rebrand the project as a "social experiment with NFTs." GAM wanted to capitalize on and participate in the trend of unauthenticated NFTs selling for substantial sums. As a result, they proved that there is an urgent demand for authenticating GLAM digital collectables offered for sale on NFT platforms.

These uses of NFTs raise the issue of digital vs physical assets and the relationship of NFTs to the different asset forms. Understanding clearly what the NFT represents is critical:

- Full or part ownership of a physical object?
- Print n in a 350 digital print series?
- A 'phygital' construct including digital and physical entities?

The physical entity could be a visit to the museum (represented by a digital ticket) or a coffee table book (represented by a digital voucher). Digital tickets or vouchers could be understood as digital twins of the physical experiences or goods they represent.

These complexities may not be evident to individuals and organisations investing in the NFT.

3.4 Collectible media assets

Collectibles include historical artefacts, memes, moments (Topshot, eternal), and redeemables (access to chats/events). The Cryptopunks are a collection of ten thousand unique virtual characters that was one of the first examples of NFTs in Ethereum. While users initially had the option of claiming a Cryptopunk for free at the time they were produced, the market for these 28-by-28 pixel avatars has grown to exceed US\$400 million in revenues. The enormous monetary value of this and other NFT-based collections, such as the NBA Top Shot, the Bored Ape Yacht Club, and the Meebits, demonstrates that proposed NFT-based solutions are ideally suited to this use case.

3.5 Gaming

The gaming community has tapped into the fascinating qualities of NFTs within its virtual worlds, using them to represent collectible things that can be traded with other gamers between games and outside of games in NFT gaming asset NFT marketplaces. These systems have drawn thousands of curious gamers and investors to platforms such as Axie infinity, CryptoKitties, and Decentraland, resulting in the creation of thriving virtual economies worth hundreds of millions of dollars.

⁵ Artnet News. The Uffizi Gallery Just Sold a Michelangelo NFT for \$170,000, and Now Is Quickly Minting More Masterpieces from Its Collection. Available online: <https://news.artnet.com/art-world/uffizi-gallery-michelangelo-botticelli-nfts-1969045>

⁶ Kishkovsky, S. Hermitage Museum Mints Leonardo, Monet, Van Gogh NFTs to Raise Funds. Available online: <https://www.theartnewspaper.com/news/nft-hermitage>

⁷ OpenGLAM Is a project that promotes free and open access to digital collections from galleries, libraries, archives and museums. The Rijksmuseum launched OpenGLAM in 2011 and it has since been adopted by major museums and galleries including the Metropolitan Museum of Art, the National Gallery of Denmark, and the Getty.

⁸ Rijksmuseum "@TinaRiversRyan@GlobalArtMuseumWedonothaveaPartnershipwithAnyofTheseParties.OurCollectio nis for Everyone. <https://twitter.com/rijksmuseum/status/1370718093304066048> (accessed on 20 Jan 2022).

3.6 Ticketing

NFTs pose a potential solution to the difficulties with primary and especially secondary markets in ticket resales. Currently ticket sales to popular sporting events, concerts and other events are subject to a range of scamming techniques. Such scams include bulk buying of initial release tickets for resale on secondary markets at exorbitant prices. Fraudulent tickets can and have led to buyers being refused access to the event.

Trends in governance of ticket issues are focussing on securing the ability of legitimate buyers to have a reasonable opportunity to purchase tickets in initial ticket releases and reduce ticket 'scalping'. This concern extends to governmental control, for example recently a 2024 Taylor Swift concert tour was declared by the Australian Victorian state government as a major event, bringing the concerts under the umbrella of anti-scalping legislation. NFTs can have a role to secure tickets to authentic buyers and enable ticketing companies and the public to adhere to legislation. Furthermore they can provide a way in which event organisers can claw back secondary market profiteering by tracking and charging ticket resellers.

3.7 Sharing media assets on social media

Social media have played a major role in the popularisation and promotion of NFTs. Major social media players are also exploring ways to integrate NFT creation, storing and transactions directly into their platforms. In January 2022 Twitter introduced a feature for Twitter Blue subscribers to connect to their crypto wallet and use NFTs as a profile picture. The feature is experimental but planned to be expanded in the future to more assets than just the profile picture and more users than paid subscribers. However, some bottlenecks were already identified such as the availability of the assets during an outage of the API of the underlying blockchain platforms. While most implementations are experimental and explorative at the moment, integration of NFTs in social media has the potential to give users ways to verify content they discover as well as more control over sharing rights to their own content.

3.8 Academic certification

NFTs may have a role to play in academic certification. Academics at the University of Macau have proposed an NFT-based system, NFTCert, to replace paper-based academic certification, noting that over 300 million paper-based academic credentials are issued annually. Traditional certifications are vulnerable to forgery, loss or onerous verification procedures, which NFTs may be able to circumvent.⁹

4 Threat Vectors

This section provides an overview of threats associated with current NFT practices and implementations.

4.1 Unauthorised minting of content that does not belong to the minter (copy minting)

Several security issues have been reported wherein rightful owners of digital art have discovered that unauthorised persons have minted their art. This is creating a trust issue with the use of NFTs in art markets. This issue is problematic, especially for less-known art pieces for which it is hard to know the provenance of the latter readily. Nevertheless, even in the case of art pieces of certain widely known reputations, it has been reported that additional art pieces generated employing AI with similar style have been minted by distributing fake brochures containing such pieces in a more extensive collection of a well-known artist.

4.2 Replacement of the digital asset corresponding to the minted NFT by an alternative

Several security issues have been reported where digital assets to which an NFT is pointing has been replaced by another after the NFT has been sold. This problem brings mistrust in the adoption of NFTs in the art trade.

⁹ X. Zhao and Y. -W. Si, "NFTCert: NFT-Based Certificates With Online Payment Gateway," *2021 IEEE International Conference on Blockchain (Blockchain)*, 2021, pp. 538-543, doi: 10.1109/Blockchain53845.2021.00081.

4.3 Duplicate item registrations

The same item can be registered multiple times within one NFT chain, or with competing NFT registration services. When there are competing claims, which one is correct or legitimate? You cannot necessarily trust timestamps (e.g., who registered first) since the timestamps on different computers may not be synchronised.

While this is an issue when there is unauthorized minting (see 4.1), it is also an issue when the minter is authorized to provide an NFT of the content.

4.4 Privacy

The NFT is a pointer to a pointer to an item. If an attacker owns the middle pointer, then they can watch and track everyone who looks up the item. It does not matter that the first pointer (the DLT) is distributed since all copies of the record in the distributed ledger must point to the same middle service.

4.5 Security

Similar to the privacy problem: The NFT is a pointer to a pointer to an item. The middle pointer becomes a bottleneck and potential attack vector for a man-in-the-middle attack. As the controller of the middle pointer, the attacker knows your network address (because you connected to the pointer), your OS from your network profile, and the type of data you are expecting back. In theory, the attacker could poison the response and send you a customized attack.

4.6 Transfer of records

There are instances where a banker on the blockchain has vanished. Similarly, some blockchains may lose community support or cease to exist. When this happens, what options does an NFT holder have? Is there a mechanism to transfer NFT ownership between different blockchains?

4.7 Non regulation-compliant NFTs

NFTs which would not comply with regulations related to data (e.g., EU Data Act), IP, or financial markets including Markets in Crypto-Assets (e.g., EU MiCA).

4.8 Open access proponent resistance to NFTs

Members of open access organisations, such as Creative Commons, actively promote free and open sharing of media assets. Other organisations, such as copyright focussed Europeana Copyright, also include open access as an important element of rights management. Some proponents of open access have a negative perception of NFTs as a mechanism to create artificial scarcity, and a mechanism by which open access media can be moved behind paywalls.

4.9 NFT use of media assets at scale

An NFT becomes unwieldy and possibly unworkable when it uses dozens or hundreds of individual media assets, management of copyright and authentication mechanisms.

5 Requirements

Based on the identified use cases, an initial set of JPEG NFT requirements have been identified and organized in the following main categories:

- Compatibility
- Metadata descriptions
- Metadata embedding and referencing
- Provenance, authenticity and integrity
- Media asset registration format
- Management of intellectual property rights

The requirements identified so far are listed accordingly in the sections below. These requirements will be further elaborated and extended in future revisions of this document.

5.1 Compatibility

- R1.1 The standard shall **comply with the JPEG Systems framework** and should **retain backwards compatibility**.
- R1.2 The standard shall **align with JPEG Trust** and more specifically with its requirements as defined in wg1n100156 “Use Cases and Requirements for JPEG Fake Media”.

5.2 Metadata descriptions

- R2.1 The standard shall provide means to identify, authenticate and describe **involved actors** while considering privacy of individuals.
- R2.2 The standard shall provide means to identify and describe **media assets**.
- R2.3 The standard shall provide means to signal **IPR information** related to media assets.

5.3 Metadata embedding and referencing

- R3.1 The standard shall provide means to **embed relevant metadata descriptions** into media assets and/or to **link relevant metadata descriptions** to media assets.
- R3.2 The standard shall consider **privacy** of individuals and locations as well as **trade secrets**.
- R3.3 The standard shall provide means for **identification** of media assets and related NFTs.
- R3.4 The standard shall support **searchability** of NFTs and associated media assets.

5.4 Provenance, authenticity and integrity

- R4.1 The standard shall provide means to **trace the provenance** of NFTs.
- R4.2 The standard shall provide means to **assess the authenticity and integrity** of the media asset referred to by NFTs.

5.5 Media asset registration format

- R5.1 The standard shall provide means to **register media assets and related NFTs** while **building up on existing standards** of identifiers, metadata sets, and metadata exchanges.

5.6 Management of intellectual property rights

- R6.1 The standard shall facilitate the copyright declaration and micro-licensing of media assets (see use cases 3.1 and 3.2).
- R6.2 The standard shall facilitate the IP protection of the NFT itself.