NFTDisk: Visual Detection of Wash Trading in NFT Markets

Xiaolin Wen\textsuperscript{1,2} \quad Yong Wang\textsuperscript{2} \quad Xuanwu Yue\textsuperscript{3} \quad Feida Zhu\textsuperscript{2} \quad Min Zhu\textsuperscript{1}
Background

NFT (Non-Fungible Token)

NFT Markets

NFT Investors

Fraudulent Activities
Background

Wash Trading

Colluding Addresses → Fake Trade Volumes → NFT Investors

Create → Mislead
Motivation

Automatic Detection\cite{1} can only find a subset of wash trading due to their sophisticated patterns.

Manual Inspection is usually required, but it is hard to get useful information directly from the original transactions.

NFTDisk: a novel visualization for investors to visually identify wash trading activities in NFT markets.
NFT Disk

Disk Module

Flow Module
NFTDisk

Disk Module

Overview Transactions

Suspicious addresses
Show NFT flows among suspicious addresses at multiple levels.
Disk Module

Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Disk Module

Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Disk Module

Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Disk Module

Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.
Disk Module

A Outer Ring
- NFT Sale
- NFT Transfer

A1
- First Transaction
- Last Transaction

A3
- Background
- Average Price / Trading Volume
  Min
  Max

A4

B Inner Circle
- Address
- Height
- Inner Path

B1
- Suspicious Addresses
- Normal Address

B2

B4
- Suspicious Score
  0
  1
Disk Module

A Outer Ring

- NFT Sale
- NFT Transfer
- First Transaction
- Last Transaction
- Background
  - Average Price / Trading Volume
  - Min
  - Max

B Inner Circle

- Address
- Height
- Inner Path
- Suspicious Addresses
- Normal Address

B4 Suspicous Score
- 0
- 1

0.25 0.5 0.75 1.0
Disk Module

A Outer Ring

- A1: NFT Sale
- A2: First Transaction
- A3: Background
  - Average Price / Trading Volume
  - Min to Max
- A4: Last Transaction

B Inner Circle

- B1: Inner Path
- B2: Height
- B3: Suspicious Addresses
- B4: Normal Address

Address

Time

0.25 0.5 0.75 1.0

Suspicious Score

0 1
Flow Module
Flow Module

Stacked Area Chart
Flow Module

Flow-based Chart
Flow Module

# NFT of the whole group

transactions over time

Selected Addresses: 1 2 3 4
Flow Module
Evaluation

- Two case studies
- User interview with 14 real NFT investors
Online study with 14 NFT investors (4 females, 10 males, age_{mean} = 28)

Task:

T1. Initialize the visualization by using interactions components to filter out undesired information.
T2. Observe the Disk Module to find suspicious addresses and time periods and brush to select them.
T3. Analyze the NFT flows at the group level by the stacked area chart of the Flow Module.
T4. Brush a period in the stacked area chart and check the detailed NFT flows in the flow-based chart.
Here shows the interface of NFTDisk, it looks like a big disk with music flow around it.

**Workflow Effectiveness**

**Visual Design and Interactions**

**Usability**

<table>
<thead>
<tr>
<th>Q1</th>
<th>1</th>
<th>1</th>
<th>2</th>
<th>7</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Q3</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Q5</td>
<td>1</td>
<td>1</td>
<td>8</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Q6</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Q7</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Q8</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q9</td>
<td>1</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Q10</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Q11</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Q12</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Summary

- Cooperated with NFT investors to collect design requirements;
- Proposed NFTDisk to help investors detect and analyze wash trading;
- Conducted case studies and user interview to evaluate NFTDisk;
NFTDisk: Visual Detection of Wash Trading in NFT Markets

Xiaolin Wen¹,²  Yong Wang²  Xuanwu Yue³  Feida Zhu²  Min Zhu¹

Xiaolin Wen
wenxiaolin@stu.scu.edu.cn

Yong Wang
yongwang@smu.edu.sg
Design Requirements

- R1 Analyze wash trading in the scope of NFT collection;
- R2 Recognize suspicious transactions and addresses from the overview;
- R3 Reveal wash trading features at multiple levels;
- R4 Display the detailed transaction patterns of wash trading;
- R5 Enable the evaluation of wash trading influence.
## Participants

<table>
<thead>
<tr>
<th>ID</th>
<th>Gender</th>
<th>Age</th>
<th>NFT Experience</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>Male</td>
<td>23</td>
<td>13 months</td>
<td>A creator of an NFT community and a key opinion leader on Twitter.</td>
</tr>
<tr>
<td>U2</td>
<td>Female</td>
<td>25</td>
<td>8 months</td>
<td>A product manager for multiple NFT projects.</td>
</tr>
<tr>
<td>U3</td>
<td>Male</td>
<td>30</td>
<td>12 months</td>
<td>An NFT investor who is good at using NFT analysis tools.</td>
</tr>
<tr>
<td>U4</td>
<td>Female</td>
<td>26</td>
<td>12 months</td>
<td>A creator of an NFT community and a key opinion leader on Twitter.</td>
</tr>
<tr>
<td>U5</td>
<td>Male</td>
<td>29</td>
<td>10 months</td>
<td>A creator of an NFT community and a leader of an NFT project.</td>
</tr>
<tr>
<td>U6</td>
<td>Male</td>
<td>25</td>
<td>12 months</td>
<td>A creator of an NFT community and a leader of three NFT projects.</td>
</tr>
<tr>
<td>U7</td>
<td>Female</td>
<td>23</td>
<td>7 months</td>
<td>An NFT investor engaged in the issuance of NFT projects.</td>
</tr>
<tr>
<td>U8</td>
<td>Male</td>
<td>27</td>
<td>10 months</td>
<td>An NFT investor engaged in the issuance of NFT projects.</td>
</tr>
<tr>
<td>U9</td>
<td>Male</td>
<td>27</td>
<td>6 months</td>
<td>An NFT investor who is good at using NFT analysis tools.</td>
</tr>
<tr>
<td>U10</td>
<td>Male</td>
<td>30</td>
<td>12 months</td>
<td>An NFT investor investing in cryptocurrencies for five years.</td>
</tr>
<tr>
<td>U11</td>
<td>Male</td>
<td>25</td>
<td>7 months</td>
<td>An NFT investor investing in cryptocurrencies for two years.</td>
</tr>
<tr>
<td>U12</td>
<td>Male</td>
<td>28</td>
<td>5 months</td>
<td>An NFT investor investing in cryptocurrencies for two years.</td>
</tr>
<tr>
<td>U13</td>
<td>Male</td>
<td>46</td>
<td>4 months</td>
<td>A professor whose research focus is digital economy.</td>
</tr>
<tr>
<td>U14</td>
<td>Female</td>
<td>28</td>
<td>5 months</td>
<td>A PhD student with two-year research experience in cryptocurrencies.</td>
</tr>
</tbody>
</table>
Implications

- Lessons learned:
  - Group of addresses > Individual addresses.
  - Different addresses have different tasks.
  - Not all wash trading are “harmful”.

- Design considerations for novices users:
  - Straightforward visual design (market risk - height of flows);
  - Overview first, Details on demand;
Generalization

- Workflow => Other frauds in cryptocurrency markets:
  - e.g. money laundering

- NFTDisk => Traditional financial market:
  - e.g. stocks and bonds

- NFTDisk => Other abnormal online activities involving different participants:
  - e.g. Political Astroturfing
Case 2

Wash Trading Enhanced by Trading Rewards but Discouraged by Royalties
Address Reordering

Amount of transactions => distance matrix of addresses

Hierarchy clustering => clustering tree => optimal leaf ordering algorithm
Suspicious Score

\[ S = 1 - \frac{N}{M} \]

where \( M \) is the number of transactions between the two addresses, and \( N \) is the number of unique NFTs involved in these transactions. The higher the suspicious score, the more likely the address pair is to collude. If each transaction from a pair of addresses includes a different NFT, then their suspicious score is zero.