

Decentralized Finance (DeFi)

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1 Decentralized Finance (DeFi)

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1.1 Literature and materials

- C. Harvey, A. Ramachandran and J. Santoro: DeFi and the Future of Finance, 2021. ([Online version HERE](#))
- Github repository: <https://github.com/cafawo/DeFi>
- HTML script: <https://cafawo.github.io/DeFi/defi.html>
- Jupyter script: <https://github.com/cafawo/DeFi/blob/master/defi.ipynb>



```
[1]: # Imports
import os
import requests
import pandas as pd
import matplotlib.pyplot as plt
```

2 + 2

2 Previously on ...

2.1 Main problems to solve:

- Data integrity (cryptography)
- Decentralization (incentives aka mining)
- Standardization (e.g. ERC-20 token standard)

2.2 HASH Algorithm

A unique representation of information that does not trace back to the information.

2.3 Ethereum - ERC-20 Token

3 Decentralized Exchange (DEX)

How to build a decentralized market place for digital assets.

3.1 Current world (centralized exchange)

Paradoxically, crypto assets might live in a decentralized world, the majority of their trading (currently) does not.

Naturally, centralized exchanges use **centralized wallets** to store customer funds: * Controlled by the exchange, not the user * Target for hackers * Loss of keys or stolen keys * Often unregulated

In a decentralized system, users hold custody of their own funds!

3.2 Types of markets (exchange mechanisms)

1. **Order book** → typical exchange
2. **Request for quote** → over the counter (OTC)
3. Automated Market Making (AMM) → liquidity pools

3.3 DEX Protocol

Traditionally, laws, regulators and the exchanges themselves create rules, in order to facilitate:

- Price exploration
- Agreement to trade
- Trade settlement

A DEX protocol is a **set of audited (open source) smart contracts** that replaces the traditional set of rules.

Examples are: * Uniswap * EtherDelta * 0x

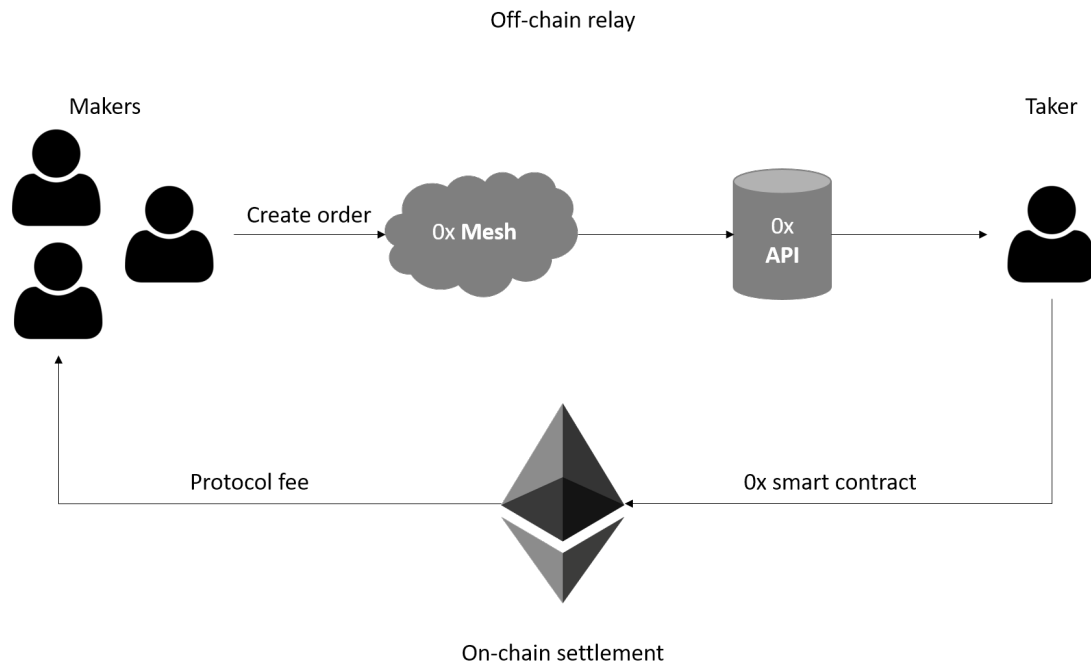
Please note that a protocol is not a user interface. This is, **we can build our own exchange UI based on an exchange protocol.**

This is a example of footnote1. Another footnote2.

footnote 1 footnote 2

DAI is a stablecoin cryptocurrency which aims to keep its value as close to one United States dollar as possible through an automated system of smart contracts on the Ethereum blockchain.

3.4 A decentralized order book protocol (0x)



3.5 Available assets

Here, assets are **tokens on the Ethereum blockchain that follow a technical standard**, such as:

- ERC-20
- ERC-721
- ERC-1155

ERC-... are technical standards have been developed after the release of ETH that allow tokens created on the Ethereum blockchain, such as ZRX, to interact with each other. (<https://ethereum.org/en/developers/docs/standards/tokens/erc-20/>)

Ether, or **ETH**, is the native token of the Ethereum blockchain. Wrapped ETH, or **WETH**, refers to an ERC-20 compatible version of ether.

```
[2]: # Request tokens that are currently available
response = requests.get('https://api.0x.org/swap/v1/tokens')
response = response.json() if response.status_code == 200 else response.
    ↳ status_code
available_tokens = pd.DataFrame(response['records'])
available_tokens
```

```
[2]:
```

	symbol	address	name \
0	ETH	0xeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeeee	Ether
1	WETH	0xc02aaaa39b223fe8d0a0e5c4f27ead9083c756cc2	Wrapped Ether
2	ZRX	0xe41d2489571d322189246dafa5ebde1f4699f498	0x Protocol Token

3	DAI	0x6b175474e89094c44da98b954eedeac495271d0f	Dai Stablecoin
4	USDC	0xa0b86991c6218b36c1d19d4a2e9eb0ce3606eb48	USD Coin
..
98	REP	0x221657776846890989a759ba2973e427dff5c9bb	Augur
99	SETH	0x5e74c9036fb86bd7ecdcb084a0673efc32ea31cb	sETH
100	STAKE	0x0ae055097c6d159879521c384f1d2123d1f195e6	xDAI Stake
101	TBTC	0x8daebade922df735c38c80c7ebd708af50815faa	tBTC
102	1INCH	0x111111111117dc0aa78b770fa6a738034120c302	1INCH

	decimals
0	18
1	18
2	18
3	18
4	6
..	...
98	18
99	18
100	18
101	18
102	18

[103 rows x 4 columns]

3.6 The order object

```
[19]: WETH_address = '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2'
# Extract a random order from the
response = requests.get(f'https://api.0x.org/orderbook/v1/orders?
↳makerToken={WETH_address}&page=1&perPage=1')
response.json() if response.status_code == 200 else response.status_code
```

```
[19]: {'total': 63,
      'page': 1,
      'perPage': 1,
      'records': [{'order': {'signature': {'signatureType': 3,
      'r': '0xfbd0358ee92b7f23750ea0d85d450f9f3e026fb3cfe2a634826d77137e3ff50b',
      's': '0x3f26904dc16d845ee8f83cdb47193ac9bb954fb0282d6de0d7101fe0ed77a8bd',
      'v': 27},
      'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
      'maker': '0xdc898b83821f6d83850622e4fd43d90b2d74d4c3',
      'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
      'takerTokenFeeAmount': '0',
      'makerAmount': '5825715981575981056',
      'takerAmount': '2257091815752258813952',
      'makerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
      'takerToken': '0x6b3595068778dd592e39a122f4f5a5cf09c90fe2',
```

```

    'salt': '1635156131651',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
    'feeRecipient': '0x0000000000000000000000000000000000000000',
    'expiry': '1635156173',
    'chainId': 1,
    'pool':
'0x0000000000000000000000000000000000000000000000000000000000000017'},
    'metaData': {'orderHash':
'0x076e65ab9d4f8355ad8289ccacc9f12e144dac48a1f240067e8331a91bdce341',
    'remainingFillableTakerAmount': '2257091815752258813952',
    'createdAt': '2021-10-25T10:02:12.284Z'}}}]

```

Some relevant fields from the order object above:

```

'order': {
  'maker': '0xc0e554c1951c0193e020156f68dce15064769937', # Address of the party that create
  'taker': '0x0000000000000000000000000000000000000000000000000000000000000000', # Address of the party that is all
  'makerAmount': '3960000000000000000000000000000000000000000000000000000000000000', # Amount of makerToken being sold by the maker
  'takerAmount': '168299999999999980000', # Amount of takerToken being sold by the taker
  'makerToken': '0xaf4c09112788ed97ac9c6284abbd2443163cfc90', # ERC20 token the maker is se
  'takerToken': '0x57ab1ec28d129707052df4df418d58a2d46d5f51', # ERC20 token the taker is se
  'feeRecipient': '0x0f8c816a31daef932b9f8afc3fcaa62a557ba2f7', # Fees to incentivize off-c
  'expiry': '1634218842',
  'metaData': {
    'orderHash': '0x00391e442ecbd9b6a16ee4c75c1c843bec166ec93ac30ffa8fd0fc62d83ebd3a', # ID f
    'remainingFillableTakerAmount': '168299999999999980000',
    'createdAt': '2021-10-14T12:40:44.426Z'}
}

```

3.7 Order book

Let's say we want exchange Ethereum against USD.

We will borrow some terminology from foreign exchange markets, i.e. * Ethereum (WETH) will be our base asset and * USD (DAI) will be out quoted asset.

Thus, we will quote the price of Ethereum in USD.

Note that USD cannot be settled on the Ethereum blockchain, hence, we will use a stable coin called DAI that is pegged to the USD (i.e. 1 DAI = 1 USD).

```

[7]: base_address = '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2' # WETH
    quoted_address = '0x6b175474e89094c44da98b954eedeac495271d0f' # DAI

    response = requests.get(f'https://api.0x.org/orderbook/v1?
    ↳baseToken={base_address}&quoteToken={quoted_address}&perPage=1000')
    order_book = response.json() if response.status_code == 200 else response.
    ↳status_code
    order_book

```

```

[7]: {'bids': {'total': 6,
  'page': 1,
  'perPage': 1000,
  'records': [{'order': {'signature': {'signatureType': 3,
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    's': '0x0baf13f642d984ac25a645da97fac80798fb2fdcf80ad5103a7843efb182b3ff',
    'v': 28},
    'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
    'makerAmount': '128437601237776373645312',
    'takerAmount': '31183476371052789760',
    'makerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'takerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'salt': '1635152576941',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
    'feeRecipient': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'expiry': '1635152618',
    'chainId': 1,
    'pool':
'0x000000000000000000000000000000000000000000000000000000000000000017'},
    'metaData': {'orderHash':
'0xf00a4ce77f47947b047cb28c28d2a291f36d345b25ac50d97dd249954861b87f',
    'remainingFillableTakerAmount': '31183476371052789760',
    'createdAt': '2021-10-25T09:02:59.080Z'}}},
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    's': '0x36a9181c855127a58cab2eef3722354f41ecac0e3c3c8c8cffe5c9528d1c890',
    'v': 28},
    'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
    'makerAmount': '128824073458150813990912',
    'takerAmount': '31281635204039090176',
    'makerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'takerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'salt': '1635152582631',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
    'feeRecipient': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'expiry': '1635152624',
    'chainId': 1,
    'pool':
'0x000000000000000000000000000000000000000000000000000000000000000017'},
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'0x19b51466022dac2df638095300d258ca3ae0d9fba96c39dd87524c3d770c4c6a',

```

```

    'remainingFillableTakerAmount': '31281635204039090176',
    'createdAt': '2021-10-25T09:03:04.207Z'}},
  {'order': {'signature': {'signatureType': 3,
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    's': '0x190e851373a8d575e8a78418620251eb00a6b85001159cc5334a626674be703b',
    'v': 27}},
    'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
    'makerAmount': '126634064209362257182720',
    'takerAmount': '30750392006494056448',
    'makerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'takerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'salt': '1635152571925',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
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    'expiry': '1635152613',
    'chainId': 1,
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    'metaData': {'orderHash':
'0x38f31015b44dadb59a55b4c72d1cef843c5bef7ae7e47779c05c9a2c08e294a0',
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    'createdAt': '2021-10-25T09:02:53.257Z'}},
  {'order': {'signature': {'signatureType': 3,
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    's': '0x04dc44834c2ee1cc8aa300c546ca8114abd615168fe2fe2d07f98e144260bf34',
    'v': 27}},
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    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
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    'takerAmount': '31041985559144235008',
    'makerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'takerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
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    'pool':
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```

```

    'createdAt': '2021-10-25T09:03:08.673Z'}}},
  {'order': {'signature': {'signatureType': 3,
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    's': '0x555087abea17dd7431d41526c74980fa8dce4522b14ab9332bb59893e907dd95',
    'v': 28},
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    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
    'makerAmount': '126634064209362257182720',
    'takerAmount': '30765547003390681088',
    'makerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'takerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'salt': '1635152593104',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
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    'remainingFillableTakerAmount': '30765547003390681088',
    'createdAt': '2021-10-25T09:03:14.849Z'}}},
  {'order': {'signature': {'signatureType': 3,
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    'v': 27},
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    'pool':
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    'createdAt': '2021-10-25T09:03:21.538Z'}}]]},

```



```

'asks': {'total': 8,
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'v': 28},
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```

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```

```

    'createdAt': '2021-10-25T09:03:08.673Z'}},
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    'v': 28},
    'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
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    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
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    'makerAmount': '35000000000000000000',
    'takerAmount': '144920568053124151902208',
    'makerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'takerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
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    'pool':
'0x000000000000000000000000000000000000000000000000000000000000000017'},
    'metaData': {'orderHash':
'0x40c563833e325d1fa1dc6f12e78c88022a8f86a03998cce3ddd32e12b20f93c6',
    'remainingFillableTakerAmount': '144920568053124151902208',
    'createdAt': '2021-10-25T09:03:08.673Z'}},
  {'order': {'signature': {'signatureType': 3,
    'r': '0xff2386d08809f9c1d4c2a760d4c8ad497b59e3bfeb98f4be077fde11b4a935b2',
    's': '0x0766e785be93c4e72ab23d476083e43594caf6d5bf75c6a166dad9318d05ea00',
    'v': 27},
    'sender': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'maker': '0x6c2d992b7739dfb363a473cc4f28998b7f1f6de2',
    'taker': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'takerTokenFeeAmount': '0',
    'makerAmount': '35000000000000000000',
    'takerAmount': '144976360905683941457920',
    'makerToken': '0xc02aaa39b223fe8d0a0e5c4f27ead9083c756cc2',
    'takerToken': '0x6b175474e89094c44da98b954eedeac495271d0f',
    'salt': '1635152572042',
    'verifyingContract': '0xdef1c0ded9bec7f1a1670819833240f027b25eff',
    'feeRecipient': '0x0000000000000000000000000000000000000000000000000000000000000000',
    'expiry': '1635152614',
    'chainId': 1,
    'pool':
'0x000000000000000000000000000000000000000000000000000000000000000017'},
    'metaData': {'orderHash':
'0x8e7b22a45c896fef9c77b46953eb383aba87de6f6e30e63393f848306237590d',
    'remainingFillableTakerAmount': '144976360905683941457920',
    'createdAt': '2021-10-25T09:02:53.257Z'}}},

```


Bid, i.e. the price at which the **taker** sells **WETH** for USD

```
'makerAmount': '17323698973795344711680', # Amount of DAI being sold by the maker
'takerAmount': '4585635752723798528',      # Amount of WETH being sold by the taker
```

Ask, i.e. the price at which the **taker** buys **WETH** for USD

```
'makerAmount': '10000000000000000000',      # Amount of WETH being sold by the maker
'takerAmount': '38006811467435057610752',    # Amount of DAI being sold by the taker
```

We could quote prices (and volumes) in WETH or DAI, here we use DAI, hence,

\$

$$Price = \frac{\text{Amount in quoted currency (e.g. DAI)}}{\text{Amount in base currency (e.g. WETH)}} \quad (1)$$

\$

```
[16]: quotes = []

for q in order_book['bids']['records']:
    if q['metaData']['remainingFillableTakerAmount'] != '0':
        # Quote: DAI received per WETH
        price = int(q['order']['makerAmount']) / int(q['order']['takerAmount'])
        # Volume in DAI (DAI is stored as bigint with 18 decimals)
        volume = int(q['order']['makerAmount']) / 10**18
        orderHash = q['metaData']['orderHash']
        quotes.append(('Bid', price, volume, f'>>> One WETH pays ${price:.2f}$ DAI',
        ↪DAI', orderHash))
for q in order_book['asks']['records']:
    if q['metaData']['remainingFillableTakerAmount'] != '0':
        # Quote: DAI paid per WETH
        price = int(q['order']['takerAmount']) / int(q['order']['makerAmount'])
        # Volume in DAI (DAI is stored as bigint with 18 decimals)
        volume = int(q['order']['takerAmount']) / 10**18
        orderHash = q['metaData']['orderHash']
        quotes.append(('Ask', price, volume, f'>>> One WETH costs ${price:.2f}$ DAI',
        ↪DAI', orderHash))

quotes = pd.DataFrame(quotes, columns=['Side', 'Price in DAI', 'Volume in DAI',
        ↪'Price taker perspective', 'Order ID'])
quotes.sort_values(by='Price in DAI', inplace=True)
quotes
```

```
[16]:
```

	Side	Price in DAI	Volume in DAI	Price taker perspective \
5	Bid	4115.805991	127407.008650	>>> One WETH pays \$4115.81\$ DAI
4	Bid	4116.099876	126634.064209	>>> One WETH pays \$4116.10\$ DAI
3	Bid	4116.794676	127793.480870	>>> One WETH pays \$4116.79\$ DAI
2	Bid	4118.128451	126634.064209	>>> One WETH pays \$4118.13\$ DAI
1	Bid	4118.201386	128824.073458	>>> One WETH pays \$4118.20\$ DAI

```

0  Bid    4118.771099  128437.601238  >>> One WETH pays $4118.77$ DAI
6  Ask    4139.599840  41395.998405  >>> One WETH costs $4139.60$ DAI
7  Ask    4139.942413  41399.424128  >>> One WETH costs $4139.94$ DAI
8  Ask    4140.188676  41401.886760  >>> One WETH costs $4140.19$ DAI
9  Ask    4140.587659  144920.568053  >>> One WETH costs $4140.59$ DAI
10 Ask    4142.181740  144976.360906  >>> One WETH costs $4142.18$ DAI
11 Ask    4142.657994  41426.579939  >>> One WETH costs $4142.66$ DAI
12 Ask    4142.884556  145000.959461  >>> One WETH costs $4142.88$ DAI

```

Order ID

```

5  0x4fbb605f6e760fc8a02cd9d95651fd717a9a47157463...
4  0xa51678c1492c07bcee639896120168b19d205b2cf060...
3  0x89c37b3cf804db8fa4bc9450625128eea02c231bc75f...
2  0x38f31015b44dadb59a55b4c72d1cef843c5bef7ae7e4...
1  0x19b51466022dac2df638095300d258ca3ae0d9fba96c...
0  0xf00a4ce77f47947b047cb28c28d2a291f36d345b25ac...
6  0x9dce7b80741c6cbd514ab94e01746ed54069e71048c8...
7  0x381d3bcf18c55afcef85a465b9c3c8438698f7b9d2e8...
8  0x5cf7d80667078615af327f9400c016c2fe61a8858257...
9  0x40c563833e325d1fa1dc6f12e78c88022a8f86a03998...
10 0x8e7b22a45c896fef9c77b46953eb383aba87de6f6e30...
11 0x82968253357ef2a68866be3a1e6bc11671feee722fb4...
12 0xbcde44bc609d81f9f49696e89e7aedb70424e932db35...

```

3.8 Submitting an order

3.8.1 Market order

Submit orders for the lowest available purchase or highest possible sale price.

3.8.2 Limit order

Submit orders with a condition on the execution price.

4 Coming up ...

4.1 Automated Market Making (AMM)

- AMM system where the taker trades against a liquidity pool.
- Uniswap example

4.2 Efficiency and arbitrage

- Discussion of protocols and their problems
- Price exploration and trading between protocols

[20]: *# This is just generating the HTML and PDF version of the script.*

```
# jupyter nbconvert vdt.ipynb --to slides --post serve --SlidesExporter.  
↪ reveal_scroll=True  
local_dir = %pwd  
os.system(f'jupyter nbconvert defi.ipynb --to html')  
# Generate PDF  
os.system(f'jupyter nbconvert {local_dir}/defi.ipynb --to pdf')
```

[20]: 0

[]: