Interoperable Mechanisms for Non-rival Goods

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Plan of this talk

1. **Taxonomy** of goods and funding transactions
2. Interoperability via "**hypercertificates**"
   - Analogy to ERC-1155, or Cede & Co. ledger
3. Brief orientation to **mechanisms**

Section 1

Taxonomy

Characteristics of goods

A good is…	to the extent that…
rival	
excludable	
transferable	
divisible	
fungible	

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- Aside: Stallman's 4 Freedoms are essentially orthogonal; they're about control, not cost. At least 3/4 may be compatible with toll goods.

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- Improving markets/liquidity for assessing & rewarding the benefits could grow the feasible range & time-scale

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  - Disadvantage: success conditions must be accurately anticipated, articulated, and evaluated, all in advance
- Important to have a structure to route (some) retrospective and bountied rewards as returns to prospective funders
  - Although also important to retain the option to give no-strings-attached grants, at any stage.

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  - “toll-driven” retrospective rewards (paid in exchange for access to toll goods created by the project, e.g. a walled garden, or an IP pool)

Let Many Flowers Bloom

	Prospective	**Bountied**	**Retrospective**
No-strings	Grants	Bounties	Retroactive public goods funding
Bragging rights	Impact grants	Results oracles	Certificate-of-impact purchases
Transferable right	Impact investments	Project-token market-makers	Project-token open market
Toll income	~VC funding	IP bounties	IP purchases, startup acquisitions

- None are clearly dominated by others
- Want all (and more) to work—and work **together** wherever possible

Section 2

Interoperability via hypercertificates

Hypercertificates

- This section proposes a new kind of ledger for tokenized certificates that
  - are NFT-like in some dimensions
  - but fundamentally *are fungible* (like stock certificates)
  - facilitate allocating retrospective rewards to prospective funders (or not)
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- Intuition: fractional territorial claims on a hypercubic *region* of public-goods space

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- Buyer beware: c may, or may not, have ever done anything useful related to W!
  - But whatever they did do, they own!

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- If one identity x owns at least q of all S_i:

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Atomic Merge-and-Allocate of Hypercertificates

- Given two collections of disjoint hypercert specs (S_i) and (T_j) that both add up to the same region X:

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- Maintains invariants & verifies authorization, but bring your own bargain $(q'_{j,k})$!

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- Arguably, true bragging rights should also be *permanent*, meaning:
  - T_F should extend out to $t = \infty$ to be eligible for burning
  - Burned hypercerts should be non-transferable
- Also:
  - No hypercert that has a non-empty intersection with a burned hypercert can ever be minted
  - It's invalid to send profits to a burned hypercert; the *profits* aren't burned, just relinquished.
    - If 100% of toll-income rights to a given $W \times T_W$ are burned, then, in principle, the associated goods should be released to the public domain.

Asessing Hypercertificates

- Motivation:
  - The contributor set C in the ledger will never be *really* comprehensive—Newton, Gauss, Turing unlikely to sign messages.
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- Slogan: **permissionless, but not trustless**. Assessors are T3Ps, and play a crucial role in giving bragging rights a seal of legitimacy.
- For patentable contributions, can start with existing institutions & norms for inventorship.

How *should* credit be allocated, ideally?

- I set out to answer this question from first principles and accidentally rediscovered **Shapley value**, which for a contributor $c \in C$ and utility function $V : 2^C \to \mathbb{R}$ is:

$$\phi_V(c) = \frac{1}{n!} \sum_{\sigma : C \simeq [n]} \overbrace{V\{c_i | \sigma(c_i) \leq \sigma(c)\} - V\{c_i | \sigma(c_i) < \sigma(c)\}}^{\text{marginal value of contributor } c \text{ in ordering } \sigma}$$

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- Shapley value is the unique allocation with all these properties:
  - **Budget-balance:** $\sum_{c \in C} \phi_V(c) = V(C)$
  - **Null player:** $\phi_V(c) = 0$ if $V(S \cup \{c\}) = V(S)$ for all $S \subseteq C$
  - **Symmetry:** $\phi_V(c) = \phi_V(d)$ if $V(S \cup \{c\}) = V(S \cup \{d\})$ for all $S \subseteq C$
  - **Linearity:** $\phi_{V+W} = \phi_V + \phi_W$ for all $V, W : 2^C \to \mathbb{R}$

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  - **Null player:** $\phi_V(c) = 0$ if $V(S \cup \{c\}) = V(S)$ for all $S \subseteq C$
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  - exponentially hard to compute as C grows; there are different approximations

How *should* credit be allocated, ideally?

- I set out to answer this question from first principles and accidentally rediscovered **Shapley value**, which for a contributor $c \in C$ and utility function $V : 2^C \to \mathbb{R}$ is:

$$\phi_V(c) = \frac{1}{n!} \sum_{\sigma : C \simeq [n]} \overbrace{V\{c_i | \sigma(c_i) \leq \sigma(c)\} - V\{c_i | \sigma(c_i) < \sigma(c)\}}^{\text{marginal value of contributor } c \text{ in ordering } \sigma}$$

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- Why doesn't this just solve it?
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- My *suggestion* is that assessors and contributors making private deals try to approximate Shapley value $(q'_{j,k} \approx \phi_{V_j}(c_k))$ for some appropriate (V_j) and C.

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  - Nash bargaining solution
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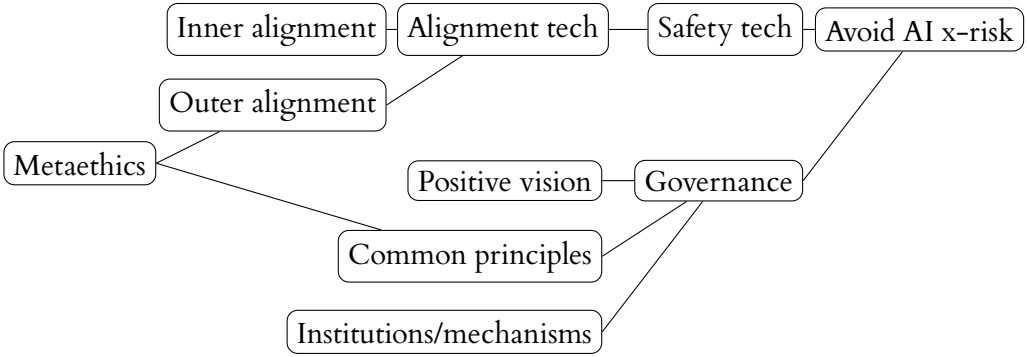
- Which pairings have good/best theoretical/pragmatic properties is future work

What does a roadmap look like?

Example toy roadmap (for AI x-risk):



A formal roadmap would specify probability distributions for each milestone's completion time conditional on its inputs.

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- Full realization of this would subsume the “important, tractable, neglected” heuristics.

Conclusions

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  - goods to carve out and price (different choices of R)
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  - Exciting threshold: FundingTheCommons has reached escape velocity!

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  - Eliana Lorch
  - Juan Benet
  - Evan Miyazono
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  - and others

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Questions?

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FundingTheCommons

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