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Bayesian Networks and decisions

July 2020

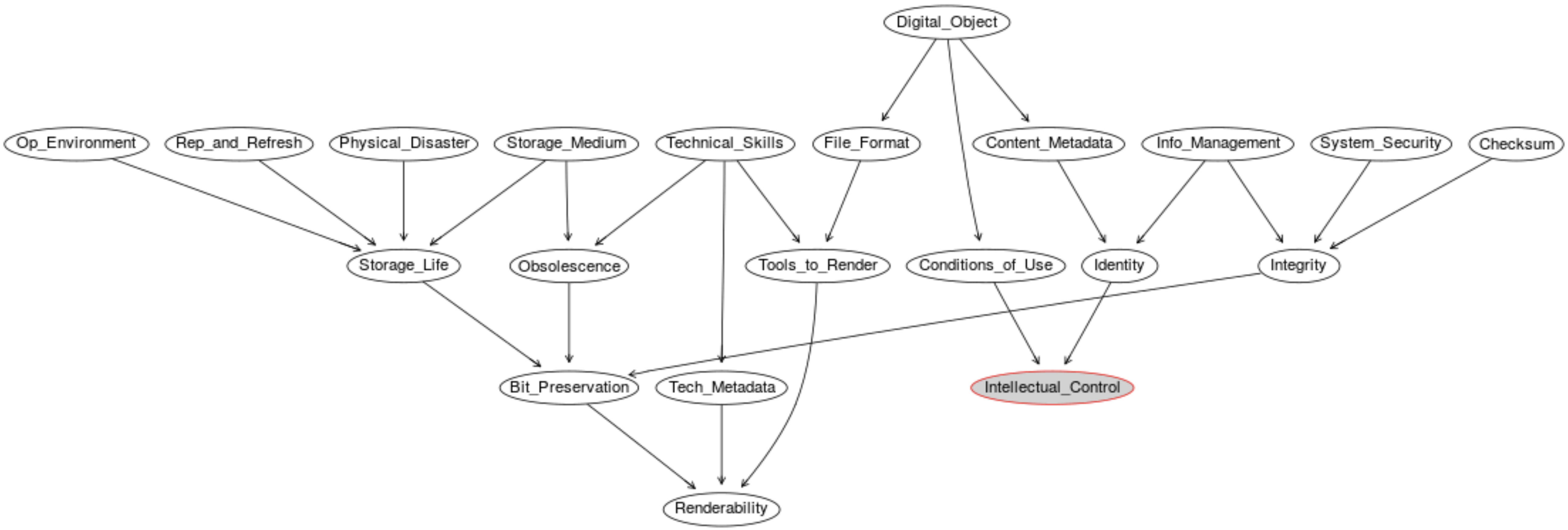
Contents

- Bayesian networks;
- Utility computation and policy comparison.

Decision under uncertainty

- Policy-makers often need to make evidence-based decision about complex systems.
- One challenge is how to combine the information provided by <u>many factors</u> and how use this information to <u>evaluate candidate policies</u>.
- In this context, <u>Bayesian Networks</u> offer a useful approach designed to accommodate uncertainties about factors affecting the system.
- In BN, structured <u>expert judgement</u> can be considered when data is not available.

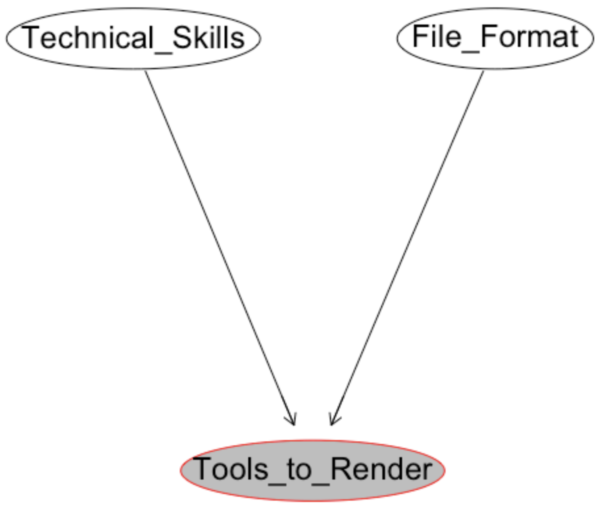
Qualitative representation of a digital preservation system

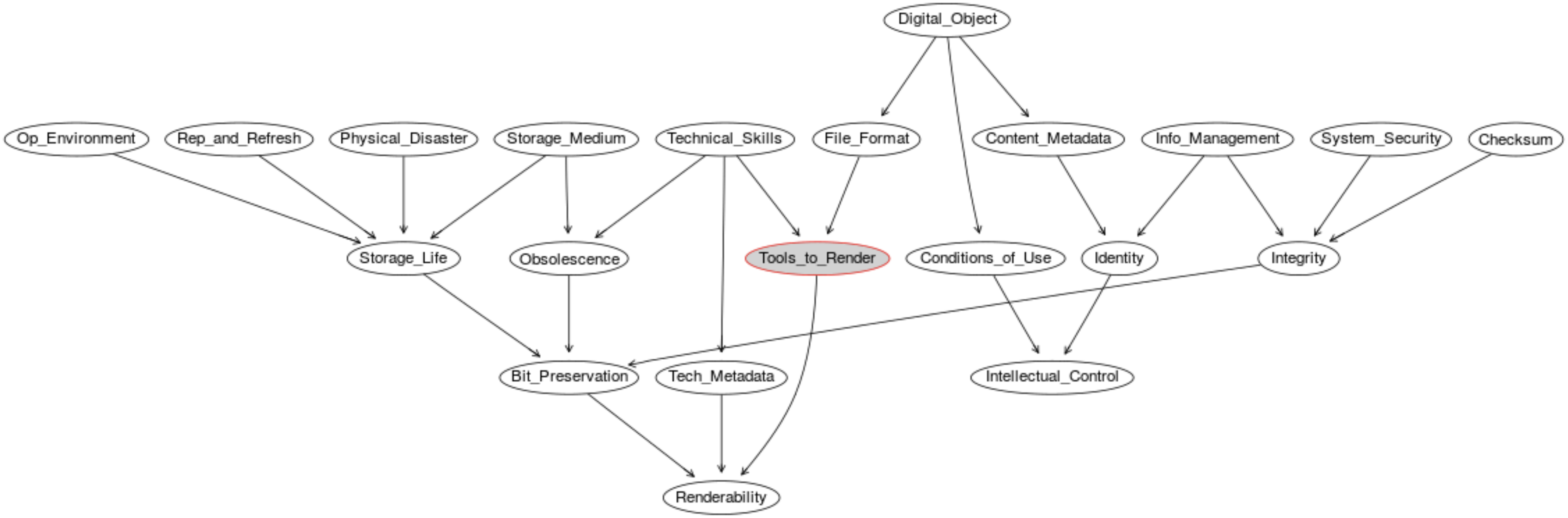


Bayesian network - The main goal is to decompose a complex system into simpler subsystems.

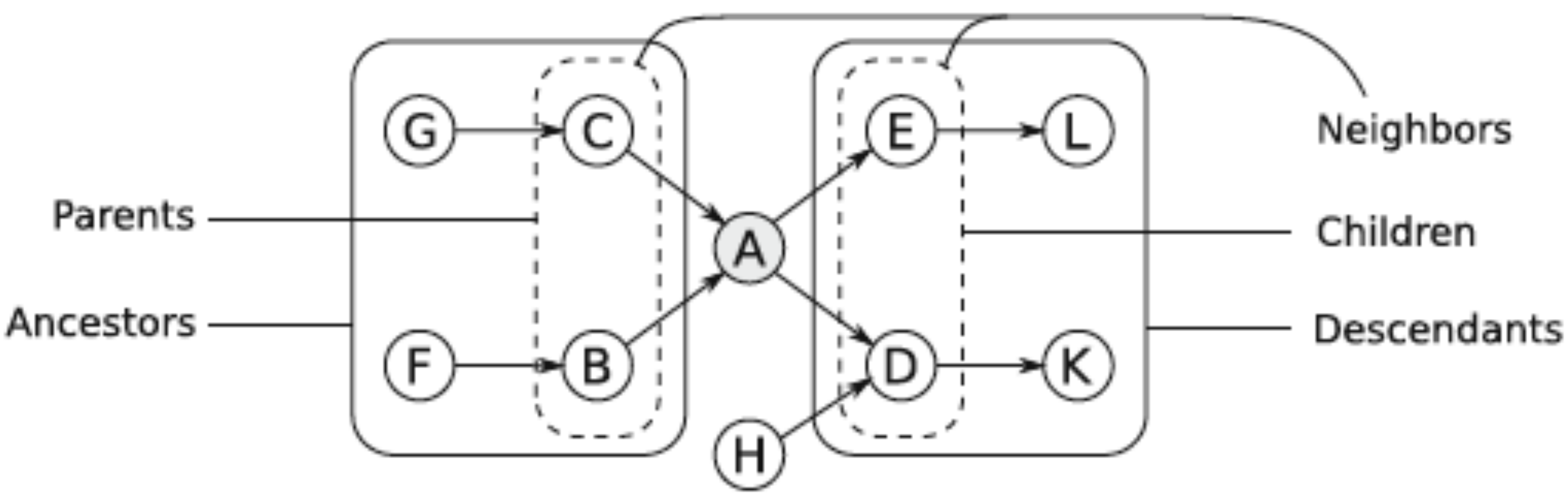
Dividing to conquer

- For instance, tools to render depend directly on technical skill and file format, but do not depend directly on Storage medium.





Structure of a BN



- G is an ancestor of A and L is a descendant of A.
- E is a child of A and C is a parent of A.

Source: Bayesian Networks in R

Basic elements of a BN

- A Bayesian network (Pearl, 1988) is defined by two basic elements:

A graph G with each node corresponding to a variable	+	A set of local conditional distributions.

Steps to compare several policies

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- Construct the network structure (define all variables and connections);
- Elicit or estimate the conditional probability tables;
- Estimate the marginal probabilities;
- Obtain the expected utility for each policy;
- Compare utilities which will be available to aid the decision maker.

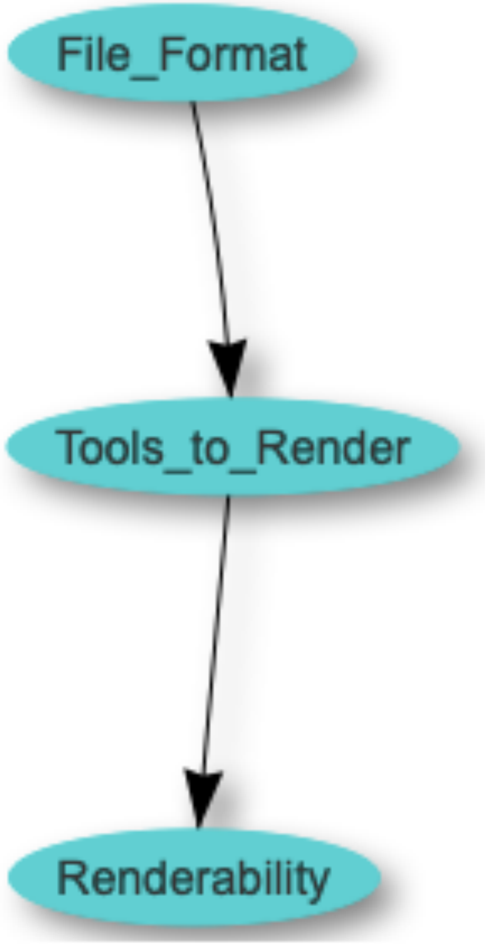
DiAGRAM

Decision under uncertainty

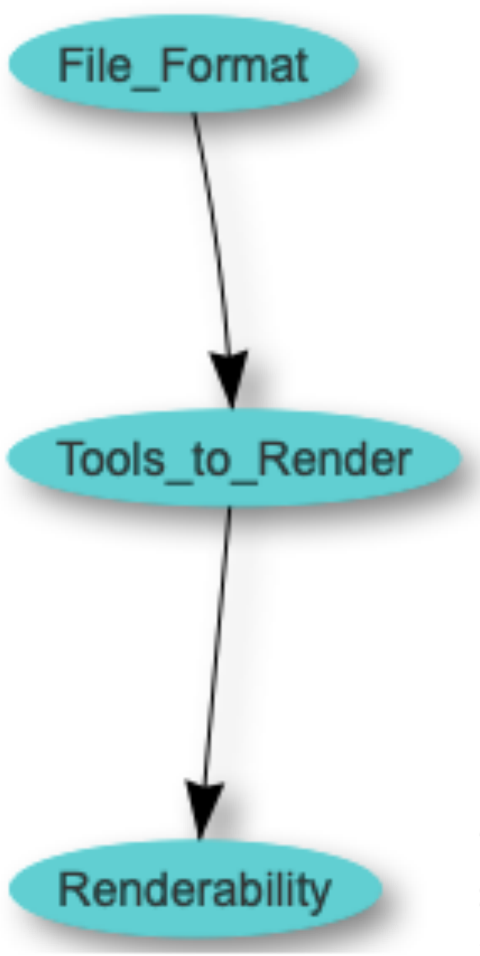
- In the context of decision under uncertainty, we need a method to combine uncertain statements and knowledge about states of “the world”.
- Probability theory is the prevailing method for dealing with uncertainty, and it is the one in focus here.
- Having combined all the available information, expected utilities can be provided to support decisions.

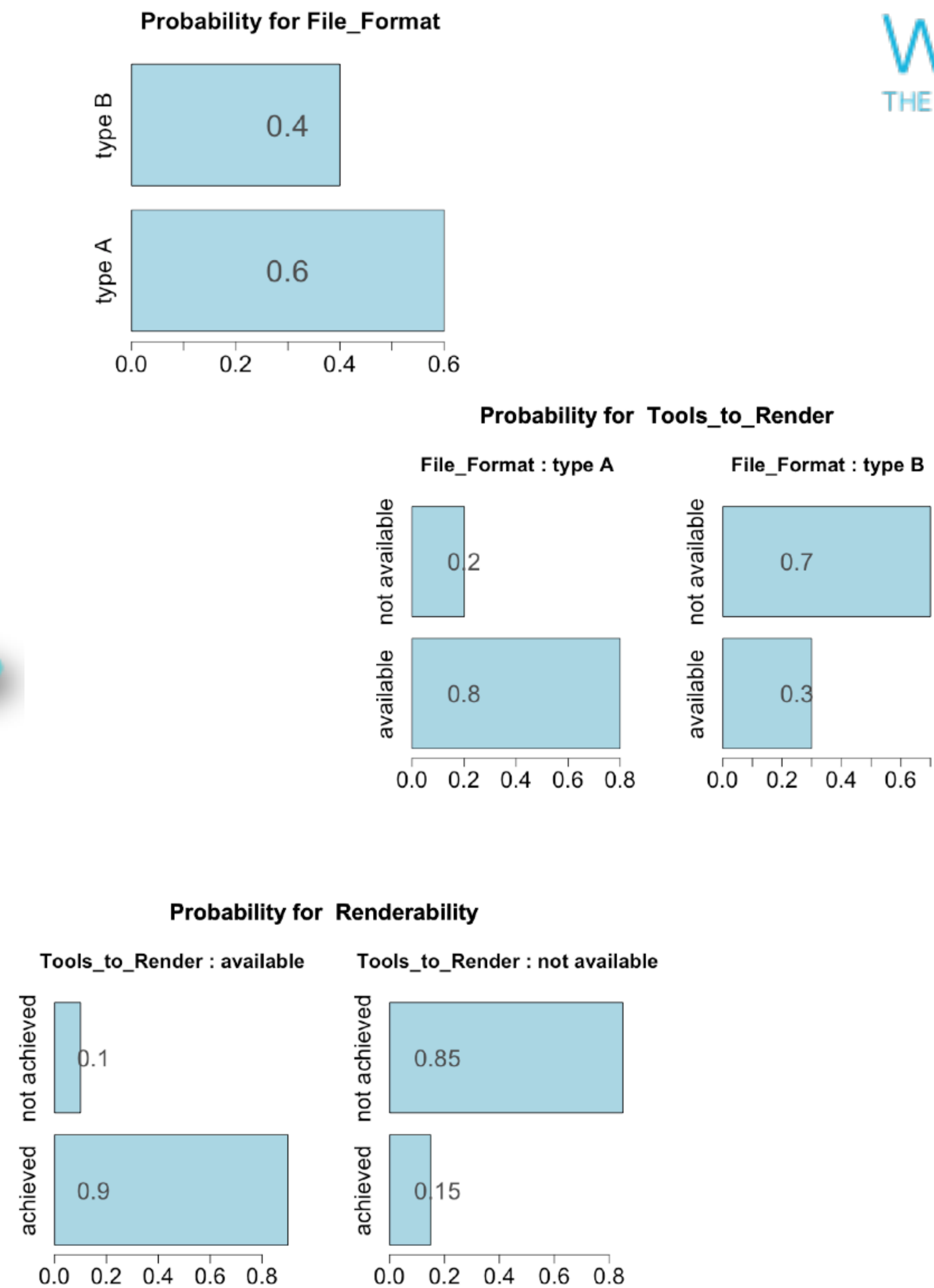
Digital preservation example

- Consider a digital preservation system depending on 3 variables only: **file format, tools to render and renderability**.
- File format are either type A or type B;
- Tools to render are either available or not available;
- And renderability is considered either achieved or not achieved.



Local probabilities





Utility computation

- Suppose that there are two policies available:
  - Policy 1: “acquire a new tool to render" with
    - utility **2** if renderability is achieved and
    - utility **1** if renderability is not achieved;
  - Policy 2: “no changes in the system” with
    - utility **0.5** if renderability is achieved and
    - utility **4** if renderability is not achieved;

	renderability is achieved	renderability is not achieved
Policy 1 (new tool)	2	1
Policy 2 (no changes)	0.5	4

If I knew that renderability would be achieved, I would recommend policy 1.

What is the best decision?

Maximizing utilities

- The preferences must be expressed on a numerical scale through utilities.

$$P \succ Q <=> u(P) \geq u(Q).$$

- Recommendations are based on the principle of ***maximal expected utility***.

Note that a potentially complex decision is replaced by the comparison of real numbers.

Utility computation

- In our example:

	renderability is achieved	renderability is not achieved
Policy 1 (new tool)	2	1
Policy 2 (no changes)	0.5	4

- P(Renderability=achieved)=0.6 is computed from the probability tables and expected utilities can be obtained.
    - E[U(policy 1)] = (0.6 x 2) + (0.4 x 1) = 1.6
    - E[U(policy 2)] = (0.6 x **0.5**) + (0.4 x **4**) = ***1.9***
- The best decision is **policy 2** (no changes in the system).
- Note that if P(Renderability=achieved)=0.7 the best decision would be policy 1 (acquire a new tool).