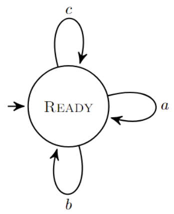
In order to respond to the following exercise, we first introduce you to some fundamental concepts.

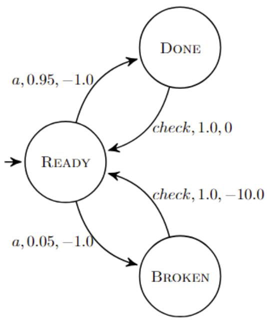
In our study, we represent manufacturing assets (machines, operators,…) as services. We distinguish two types of services: stateless and stateful services.
A **stateless service** is a service without control flow constraints, while, a **stateful service** is a service including precedence constraints, meaning its control flow is explicitly defined.

These two types of services require distinct modeling approaches:

- Stateless services can be modeled as flower graphs, which operate without dependencies on the order in which the operations are invoked. Instead of focusing on the control flow, these services emphasize the data flow.
  An example of a flower graph is the following:

  where the service has only one state (READY) and has three transitions (a,b,c) in any order.
- Stateful services can be modeled using Markov Decision Processes (MDPs), which allow for explicit definition of control flow constraints. This adds complexity to the model but significantly enhances its expressive power, by specifying the various states, probabilities, and dependencies existing.
  An example of MDP is the following:

  where, the service has three states (READY, DONE, BROKEN) and has two types of transitions (a, check), which have different probabilities and rewards depending on the state they are executed on. Ex. 'a, 0.95, -1.0' represents the transition of the action 'a' executed with a probability 0.95 with a reward of -1.0.

<u>If you are unfamiliar with MDPs, here is a quick overview:</u>
A **Markov Decision Process** consists of the following components: *(a)* a set of all possible **states** the system can be in. Each state represents a possible situation or configuration of the environment; *(b)* a set of all possible **actions** that the agent can take; *(c)* a **probability distribution** that defines the likelihood of moving from one state to another, given a specific action; and, *(d)* a **reward function** that assigns a numerical value (reward) to each transition between states based on the action taken.

EX1.

Given the following text, *model the manufacturing assets* involved in the process, specifying the operations over the transitions. Do not focus on the process itself.

In an automated car assembly line, there are two robotic arms. One is able to perform welding and the other performs painting. Furthermore, the two robotic arms require a human operator to approve the various tasks they perform. The performed operations in the assembly line follow a specific order, i.e., the robot welder welds the car frame with the approval of the human operator, and afterward the robot painter paints the car (after the approval of the human operator). The employed robotic arms are subject to ruptures that affect the ability of performance. Each robotic arm operates in five phases, i.e., ready, configured, operational, rupture, and repair, and can transition between these phases based on certain probabilities that you can invent. The human operator is always available and only responsible for approving or not the tasks.

EX2.

Given the following text, *model the manufacturing assets* involved in the process. Do not focus on the process itself.

In an automated packaging line, three identical machines are able to perform sealing, labeling, and boxing products. These machines operate independently from each other and the order in which these tasks are performed does not impact the outcome of the process. For example, labeling can occur before or after boxing.