

# Production System in AI

Artificial Intelligence is one of those exciting technologies that are applicable in every field. It provides automation in almost every sector. How is it achievable? AI-based software uses a production rule system to create Artificial Intelligence algorithms. These algorithms are fed to the software for execution. In this blog, we will learn about the production system in AI, and we will see how to use production rules to solve a problem with the help of a use case.

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## Production System in Artificial Intelligence



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Let us have a glance at what all concepts you will learn in this blog on the production system in AI:

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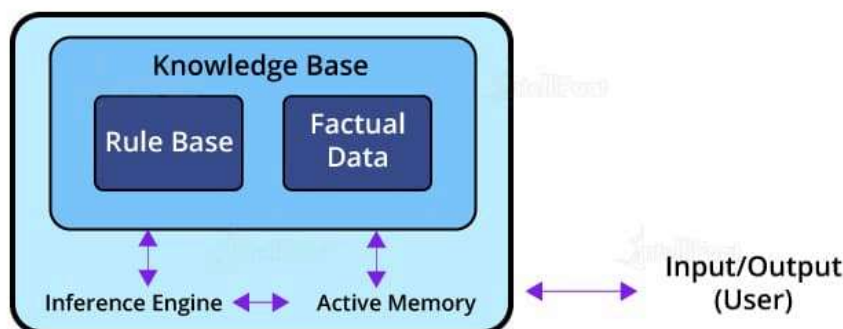
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## What is a Production System in AI?

A production system in AI is a framework that assists in developing computer programs to automate a wide range of tasks. It significantly impacts the creation of AI-based systems like computer software, mobile applications, and manufacturing tools. By establishing rules, a production system empowers machines to demonstrate particular behaviors and adapt to their surroundings.

In Artificial Intelligence, a production system serves as a cognitive architecture. It encompasses rules representing declarative knowledge, allowing machines to make decisions and act based on different conditions. Many expert systems and automation methodologies rely on the rules defined in production systems to guide their behavior.



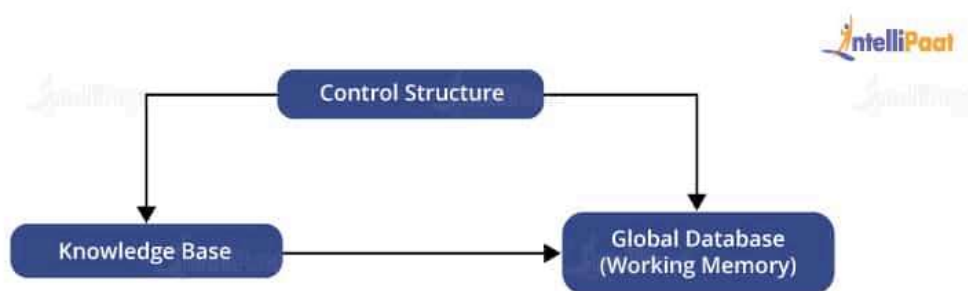
A production system's architecture consists of rules structured as left-hand side (LHS) and right-hand side (RHS) equations. The LHS specifies the condition to be evaluated, while the RHS determines the output or action resulting from the estimated condition. This rule-based approach forms the foundation of production systems in AI, enabling machines to process information and respond accordingly.

The representation of knowledge in AI comprises various components used for making intelligent machines. In the next section, we will discuss the important components of a production system in Artificial Intelligence.

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# Components of a Production System in AI

For making an AI-based intelligent system that performs specific tasks, we need an architecture. The architecture of a production system in Artificial Intelligence consists of production rules, a database, and the control system.



Let us discuss each one of them in detail.

## Global Database

A global database consists of the architecture used as a central data structure. A database contains all the necessary data and information required for the successful completion of a task. It can be divided into two parts as permanent and temporary. The permanent part of the database consists of fixed actions, whereas the temporary part alters according to circumstances.

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## Production Rules

Production rules in AI are the set of rules that operate on the data fetched from the global database. Also, these production rules are bound with precondition and postcondition that gets checked by the database. If a condition is passed through a production rule and gets satisfied by the global database, then the rule is successfully applied. The rules are of the form  $A \rightarrow B$ , where the right-hand side represents an outcome corresponding to the problem state represented by the left-hand side.

## Control System

The control system checks the applicability of a rule. It helps decide which rule should be applied and terminates the process when the system gives the correct output. It also resolves the conflict of multiple conditions arriving at the same time. The strategy of the control system specifies the sequence of rules that compares the condition from the global database to reach the correct result.

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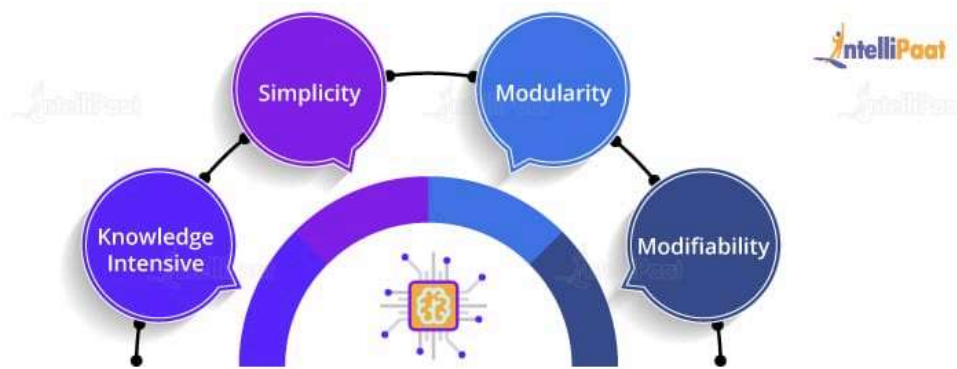
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## Characteristics of a Production System

There are mainly four characteristics of the production system in AI that is simplicity, modifiability, modularity, and knowledge-intensive.



### Simplicity

The production rule in AI is in the form of an 'IF-THEN' statement. Every rule in the production system has a unique structure. It helps represent knowledge and reasoning in the simplest way possible to solve real-world problems. Also, it helps improve the readability and understanding of the production rules.

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### Modularity

The modularity of a production rule helps in its incremental improvement as the production rule can be in discrete parts. The production rule is made from a collection of information and facts that may not have dependencies unless there is a rule connecting them together. The addition or deletion of single information will not have a major effect on the output. Modularity helps enhance the performance of the production system by adjusting the parameters of the rules.

### Modifiability

The feature of modifiability helps alter the rules as per requirements. Initially, the skeletal form of the production system is created. We then gather the requirements and make changes in the raw structure of the production system. This helps in the iterative improvement of the production system.

### Knowledge-intensive

Production systems contain knowledge in the form of a human spoken language, i.e., English. It is not built using any programming languages. The knowledge is represented in plain English sentences. Production rules help make productive conclusions from these sentences.

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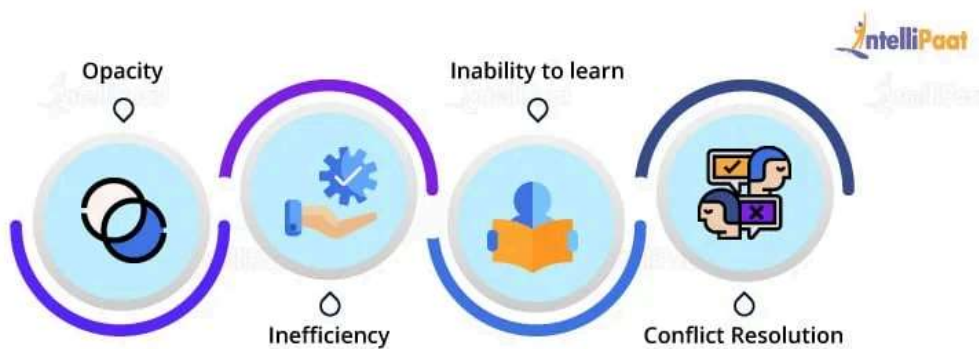
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## Disadvantages of a Production System

We discussed various features of a production system in the previous section. However, many disadvantages are also there in a production system in Artificial Intelligence, and they are as given below:



### Opacity

Communication between the rule interpreter and the production rules creates difficulty for the understanding of the control system and its strategies. This condition arises due to the impact of the combined operation of the control program. There exist difficulties in understanding the hierarchy of operations.

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### Inefficiency

There are various rules that we employ for solving a problem. The rules can be effective in different ways. There are conditions where multiple rules get activated during execution. All the individual rules apply exhaustive searches in each cycle that reduces the efficiency of the production system.

### Inability to Learn

A simple production system based on certain rules is not capable of learning through experience, unlike advanced AI systems. They are simply bound to specific rules for actions. We can understand the rules and break them.

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### Conflict Resolution

To satisfy a condition, various production rules are employed. The condition may arise when there is a triggering of more than one rule. In that condition, the control system has to determine the best possible rule from the set of conflicting rules. This may reduce the efficiency of the production system.

## Classes of a Production System

There are four types of production systems that help in categorizing methodologies for solving different varieties of problems. Let us have a look at each one of them.

### Monotonic Production System

In this type of a production system, the rules can be applied simultaneously as the use of one rule does not prevent the involvement of another rule that is selected at the same time.

### Partially Commutative Production System

This class helps create a production system that can give the results even by interchanging the states of rules. If using a set of rules transforms State A into State B, then multiple combinations of those rules will be capable to convert State A into State B.

### Non-monotonic Production System

This type of a production system increases efficiency in solving problems. The implementation of these systems does not require backtracking to correct the previous incorrect moves. The non-monotonic production systems are necessary from the implementation point of view to find an efficient solution.

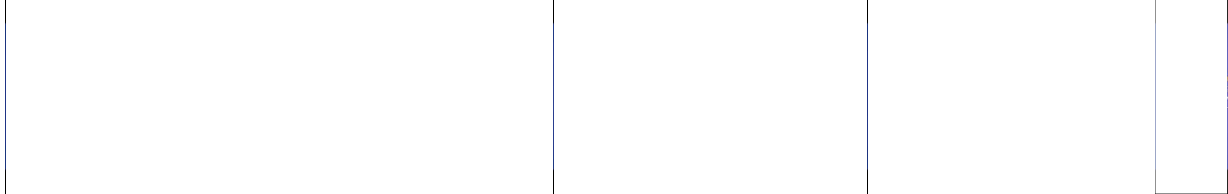
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## Commutative System

Commutative systems are helpful where the order of an operation is not important. Also, problems where the changes are reversible use commutative systems. On the other hand, partially commutative production systems help in working on problems, where the changes are irreversible such as a chemical process. When dealing with partially commutative systems, the order of processes is important to get the correct results.

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## Inference Rules

There are many production rules in Artificial Intelligence. One of them is the inference rule. It is a type of rule that consists of a logical form used for transformation. Let us look at the types of [inference rules in AI](#):

### Deductive Inference Rule

It consists of a logic that helps reasoning with the help of multiple statements to reach a conclusion.

Let us understand with the help of an example:

#### Example:

Statement 1: All mammals are animals.

Statement 2: Dogs are mammals.

Conclusion: Therefore, dogs are animals.

In this example, we have two statements: "All mammals are animals" and "Dogs are mammals." We can use deductive inference to draw a logical conclusion based on these statements.

Using the deductive inference rule of categorical syllogism, which states that if the major premise ("All mammals are animals") and the minor premise ("Dogs are mammals") are true, then the conclusion ("Therefore, dogs are animals") is also true.

By applying deductive inference to the given example, we can conclude that dogs are indeed animals based on the statements provided.

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### Abductive Inference Rule

This rule helps explain the conclusion most simply by using the given observations.

Let's explore an example to understand the abductive inference rule:

#### Example:

Observation 1: The ground is wet.

Observation 2: There are dark clouds in the sky.

Conclusion: It might have rained.

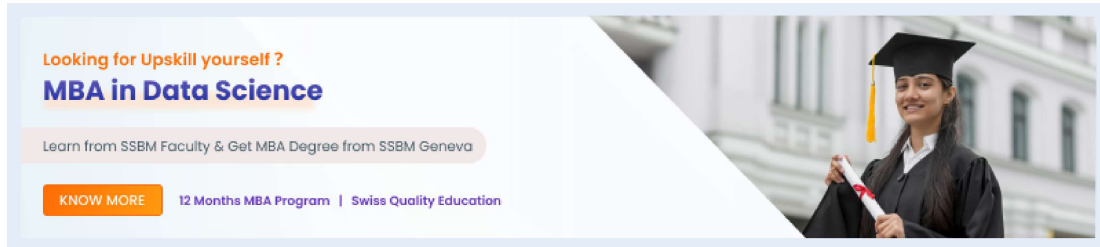


In this example, we have two observations: "The ground is wet" and "There are dark clouds in the sky." We can use abductive inference to generate a plausible explanation or hypothesis that best explains these observations.

The abductive inference rule suggests that the simplest and most likely explanation that can account for the given observations should be considered. In this case, the most straightforward explanation is that it might have rained. The wet ground and the presence of dark clouds in the sky are consistent with the hypothesis that rain occurred.

Now, we will take a look at a use case to understand how to use production rules to solve a problem.

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## Use Case: Sorting a String in a Production System

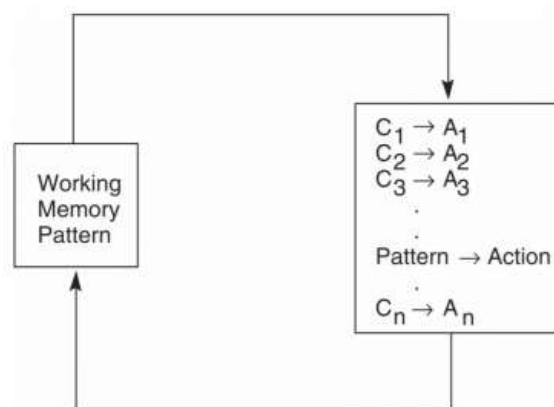
In the previous sections of this blog, we discussed the details of a production rule. Now, we will understand the use of production rules with an example of sorting a string.

**Initial String:** 'cbaca'

**Final String:** 'aabcc'

Let us look at the mechanism for sorting a string using the production system in AI.

- The production rules that we use for sorting will be enabled when it satisfies the condition by finding the sub-string in memory.
- When a particular rule is selected, it replaces the matched string by the string present on the right-hand side of the production rule.
- The loop of production rules will iterate until it finds the correct output.



Let us look at a basic production rule that can be used in this case:

1.  $ba \rightarrow ab$
2.  $ca \rightarrow ac$
3.  $cb \rightarrow bc$

Now, the below diagram will show the execution of the rules for converting the string.

| Iteration # | Working memory | Conflict set | Rule fired |
|-------------|----------------|--------------|------------|
| 0           | cbaca          | 1, 2, 3      | 1          |
| 1           | cabca          | 2            | 2          |
| 2           | acbca          | 2, 3         | 2          |
| 3           | acbac          | 1, 3         | 1          |
| 4           | acabc          | 2            | 2          |
| 5           | aacbc          | 3            | 3          |
| 6           | aabcc          | Ø            | Halt       |

Here, the conflict set represents the set of all the rules that are applicable to the string. We have to decide which rule should be used.

Hence, by using three production rules and seven iterations, we are able to convert the string 'cbaca' to 'aabcc.'

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In this blog, we understood how production rules in Artificial Intelligence help provide a machine with the ability to perform a task.

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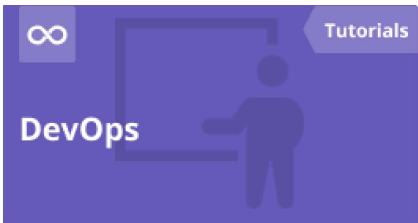
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