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What is Unification?

- Unification is a process of making two different logical atomic expressions identical by finding a substitution. Unification depends on the substitution process.
- It takes two literals as input and makes them identical using substitution.
- Let Ψ_1 and Ψ_2 be two atomic sentences and σ be a unifier such that, $\Psi_1 \sigma$ = $\Psi_2 \sigma$, then it can be expressed as **UNIFY**(Ψ_1 , Ψ_2).
- Example: Find the MGU for Unify(King(x), King(John))

Let $\Psi_1 = \text{King}(x)$, $\Psi_2 = \text{King}(\text{John})$,

Substitution $\theta = \{John/x\}$ is a unifier for these atoms and applying this substitution, and both expressions will be identical.

- The UNIFY algorithm is used for unification, which takes two atomic sentences and returns a unifier for those sentences (If any exist).
- o Unification is a key component of all first-order inference algorithms.
- o It returns fail if the expressions do not match with each other.
- The substitution variables are called Most General Unifier or MGU.

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E.g. Let's say there are two different expressions, **P(x, y)**, and **P(a, f(z))**.

In this example, we need to make both above statements identical to each other. For this, we will perform the substitution.

- Substitute x with a, and y with f(z) in the first expression, and it will be represented as a/x and f(z)/y.
- With both the substitutions, the first expression will be identical to the second expression and the substitution set will be: [a/x, f(z)/y].

Conditions for Unification:

Following are some basic conditions for unification:

- Predicate symbol must be same, atoms or expression with different predicate symbol can never be unified.
- Number of Arguments in both expressions must be identical.
- Unification will fail if there are two similar variables present in the same expression.

Unification Algorithm:

Algorithm: Unify(Ψ_1 , Ψ_2)

```
Step. 1: If \Psi_1 or \Psi_2 is a variable or constant, then:
         a) If \Psi_1 or \Psi_2 are identical, then return NIL.
         b) Else if \Psi_1 is a variable,
                 a. then if \Psi_1 occurs in \Psi_2, then return FAILURE
                 b. Else return { (\Psi_2/\Psi_1) }.
         c) Else if \Psi_2 is a variable,
                 a. If \Psi_2 occurs in \Psi_1 then return FAILURE,
                 b. Else return \{(\Psi_1/\Psi_2)\}.
         d) Else return FAILURE.
Step.2: If the initial Predicate symbol in \Psi_1 and \Psi_2 are not same, then return FAILURE.
Step. 3: IF \Psi_1 and \Psi_2 have a different number of arguments, then return FAILURE.
Step. 4: Set Substitution set(SUBST) to NIL.
Step. 5: For i=1 to the number of elements in \Psi_1.
         a) Call Unify function with the ith element of \Psi_1 and ith element of \Psi_2, and put the result into S.
        b) If S = failure then returns Failure
         c) If S ≠ NIL then do,
                 a. Apply S to the remainder of both L1 and L2.
                 b. SUBST= APPEND(S, SUBST).
Step.6: Return SUBST.
```

Implementation of the Algorithm

Step.1: Initialize the substitution set to be empty.

Step.2: Recursively unify atomic sentences:

- a. Check for Identical expression match.
- b. If one expression is a variable v_i , and the other is a term t_i which does not contain variable v_i , then:
 - a. Substitute t_i / v_i in the existing substitutions
 - b. Add t_i /v_i to the substitution setlist.
 - c. If both the expressions are functions, then function name must be similar, and the number of arguments must be the same in both the expression.

For each pair of the following atomic sentences find the most general unifier (If exist).

1. Find the MGU of {p(f(a), g(Y)) and p(X, X)}

```
Sol: S_0 => Here, \Psi_1 = p(f(a), g(Y)), and \Psi_2 = p(X, X)

SUBST \theta = \{f(a) / X\}

S1 => \Psi_1 = p(f(a), g(Y)), and \Psi_2 = p(f(a), f(a))

SUBST \theta = \{f(a) / g(y)\}, Unification failed.
```

Unification is not possible for these expressions.

2. Find the MGU of $\{p(b, X, f(g(Z)))\}$ and $p(Z, f(Y), f(Y))\}$

Here, Ψ_1 = p(b, X, f(g(Z))) , and Ψ_2 = p(Z, f(Y), f(Y))

 $S_0 = \{ p(b, X, f(g(Z))); p(Z, f(Y), f(Y)) \}$

SUBST $\theta = \{b/Z\}$

 $S_1 = \{ p(b, X, f(g(b))); p(b, f(Y), f(Y)) \}$

SUBST $\theta = \{f(Y) / X\}$

 $S_2 = \{ p(b, f(Y), f(g(b))); p(b, f(Y), f(Y)) \}$

SUBST $\theta = \{g(b)/Y\}$

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 $S_2 = \{ p(b, f(g(b)), f(g(b)); p(b, f(g(b)), f(g(b)) \}$ Unified Successfully.

And Unifier = $\{ b/Z, f(Y)/X, g(b)/Y \}$.

3. Find the MGU of $\{p(X, X), and p(Z, f(Z))\}$

Here, $\Psi_1 = \{p (X, X), \text{ and } \Psi_2 = p (Z, f(Z))\}$

 $S_0 = \{ p(X, X), p(Z, f(Z)) \}$

SUBST $\theta = \{X/Z\}$

 $S1 = \{p(Z, Z), p(Z, f(Z))\}$

SUBST $\theta = \{f(Z) / Z\}$, Unification Failed.

Hence, unification is not possible for these expressions.

4. Find the MGU of UNIFY(prime (11), prime(y))

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Here, Ψ_1 = {prime(11) , and Ψ_2 = prime(y)}

 $S_0 = \{prime(11), prime(y)\}$

SUBST $\theta = \{11/y\}$

 $S_1 = > \{prime(11), prime(11)\},$ Successfully unified.

Unifier: {11/y}.

5. Find the MGU of Q(a, g(x, a), f(y)), Q(a, g(f(b), a), x)}

Here, $\Psi_1 = Q(a, g(x, a), f(y))$, and $\Psi_2 = Q(a, g(f(b), a), x)$

 $S_0 = \{Q(a, g(x, a), f(y)); Q(a, g(f(b), a), x)\}$

SUBST $\theta = \{f(b)/x\}$

 $S_1 = \{Q(a, g(f(b), a), f(y)); Q(a, g(f(b), a), f(b))\}$

SUBST $\theta = \{b/y\}$

 $S_1 = \{Q(a, g(f(b), a), f(b)); Q(a, g(f(b), a), f(b))\},$ Successfully Unified.

Unifier: [a/a, f(b)/x, b/y].

6. UNIFY(knows(Richard, x), knows(Richard, John))

Here, Ψ_1 = knows(Richard, x), and Ψ_2 = knows(Richard, John)

 $S_0 => \{ knows(Richard, x); knows(Richard, John) \}$

SUBST $\theta = \{John/x\}$

 $S_1 = > \{ knows(Richard, John); knows(Richard, John) \},$ Successfully Unified.

Unifier: {John/x}.



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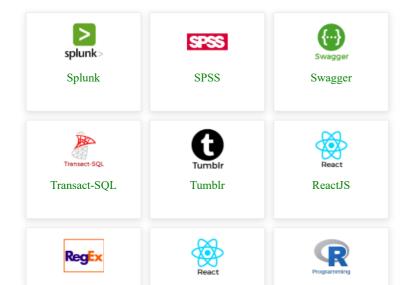
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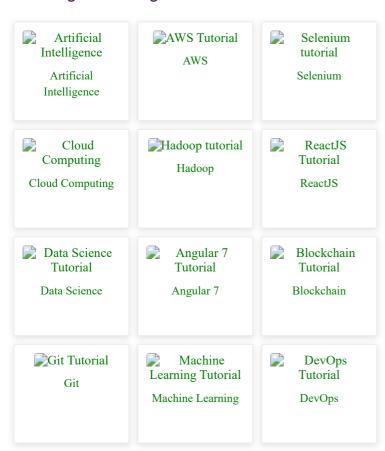




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