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A STUDY ON SELECTION OF AN INSTITUTION IN HIGHER STUDIES USING PARTIAL BIJECTIVE SOFT SET

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Abstract:

Soft set theory plays an important mathematical role in handling uncertainty and decision-making. This article introduced the new concepts of customized soft sets, partial bijective soft sets, and absolute partial bijective soft sets to utilize the intersection property. Also, define a decision formula for constructing a decision set that satisfies the critical limit under consideration. Furthermore, a new decision-making algorithm was introduced to determine the optimal choice of an educational institution for higher studies. The proposed algorithm is used to choose an institution based on key parameters, such as academic reputation, infrastructure, and placement opportunities, for the benefit of students and their parents. Additionally, relevant examples are taken to prove the results.

Keywords: Customized soft set, partial bijective soft set, absolute soft set, critical limit, decision set.

1. Introduction

In 1999, Molodtsov [8] discovered a new mathematical concept, without a membership function or probabilistic distributions for managing uncertainty is soft set theory. It is very flexible for researchers to select the parameters and make efficient or optimal decisions in the absence of some partial information. Maji et.al [6,7] developed fundamental definitions of soft sets and real-world application algorithms in decision-making problems. They [5] elaborated on the soft set concept, introducing the fuzzy soft set, which combines the properties of both fuzzy and soft sets. Ali et.al [1], and Onyeozili and Gwary [9] enriched the operations and their properties of soft sets. The soft set and fuzzy soft set theories are mainly used in decision-making problems of various fields such as medical diagnosis, supplier selection, and financial forecasting. Ke Gung et.al [4] in 2010, introduced bijective soft sets and their operations, for the application of decision-making problems. Orhan Dalkilic and Naime Demirtas [2] established a decision-making algorithm for the COVID-19 outbreak using soft set theory. Sani Danjuma et.al [3] gave an extensive study of soft set theory's applications in parameter reduction and the decision-making process.

Education is the backbone of any country's development and economic rate. Especially higher education shapes the career and personal development of a student or young citizen. Various

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institutions provide higher education programmes based on the students' interests and future employment strategy.

Selection of a higher educational institution for admission after completing schooling is a challenging and crucial situation for students and parents. The following factors play a vital role in choosing an educational institution for higher studies in recent years: students' desire, program availability within the institution, institution's reputation, academic quality, faculty expertise, tuition fee, placement opportunities, scholarship aids, transport facilities, and location.

This study provides new methods using a partial bijective soft set for making a decision on selecting an educational institution for higher studies based on students' priorities.

2. Preliminaries

In this section, we have fundamental definitions of soft sets with appropriate examples.

Definition 2.1 Soft set

Let M be a factor set linked to a universe set K. $P(K)$ is the set of subsets of K and $L \subseteq M$. An ordered 2-tuple (Ω, L) is said to be soft set [1] if the transformation $\Omega: L \to P(K)$ exists.

On the other hand, a soft set (Ω, L) over K is the system of factorized subsets of K. $\Omega(u)$ is the set of u related elements of a soft set [1] $(\Omega, L), \forall\, u \in L$.

Example 2.1

Assume, $K = \{\hbar_1, \hbar_2, \hbar_3 \hbar_4, \hbar_5, \hbar_6\}$ is the set of houses and L is the factor set for buying the house, and it is defined as follows [7]

$$L = \{e_1 = beautiful,\ e_2 = wooden, e_3 = cheap, e_4 = in\ the\ green\ suroundings, e_5 = in\ good\ repair\}.$$

Suppose that,

$\Omega(e_1) = \{\hbar_2, \hbar_4\}$, $\Omega(e_2) = \{\hbar_1, \hbar_3\}$, $\Omega(e_3) = \{\hbar_3, \hbar_4, \hbar_5\}$, $\Omega(e_4) = \{\hbar_1, \hbar_3, \hbar_5\}$,

$\Omega(e_5) = \{\hbar_1\}$, then the soft set

$(\Omega, L) = \{beautiful\ houses = \{\hbar_2, \hbar_4\};\ wooden\ houses = \{\hbar_1, \hbar_3\};\ cheap\ houses = \{\hbar_3, \hbar_4, \hbar_5\};\ in\ the\ green\ suroundings\ houses = \{\hbar_1, \hbar_3, \hbar_5\};\ in\ good\ repair\ houses = \{\hbar_1\}\}$.

Definition 2.2 Relative soft set

Let M be a factor set linked to a universe set K and $L \subseteq M$. $P(K)$ is the set of subsets of K. The soft set (Ω, L) is called a relative whole soft set [2] corresponding to a factor set L if $\forall\, u \in L,\ \Omega(u) = K$ and is represented by $\widetilde{K_L}$.

Definition 2.3 Bijective soft set

A soft set (Ω, L) over K is described as a bijective soft set [4] if it satisfies the following two conditions:

(i) $\cup_{u \in L} \Omega(u) = K$,

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(ii) For any distinct factors u_i, u_j in L, have the empty intersection of their set of u related elements.

$(i.e)$; if $u_i \neq u_j$, $u_i, u_j \in L$, then $\Omega(u_i) \cap \Omega(u_j) = \emptyset$. [4]

Example 2.2

Let us consider a soft set (Ω, E) over K, where $E = \{e_1, e_2, e_3, e_4\}$ and $K = \{x_1, x_2, x_3, x_4, x_5, x_6, x_7\}$. The mapping of (Ω, E) is explained as below:

$\Omega(e_1) = \{x_1, x_2, x_3\}$, $\Omega(e_2) = \{x_4, x_5, x_6\}$, $\Omega(e_3) = \{x_7\}$, $\Omega(e_4) = \{x_4, x_5, x_6, x_7\}$. From definition 2.3 $(\Omega, \{e_1, e_2, e_3\})$ and $(\Omega, \{e_1, e_4\})$ are bijective soft sets [4].

3. Partial Bijective Soft Set

Definition 3.1 Customized soft set

If (Ω, L) is a soft set over K, according to the function $\Omega: L \rightarrow P(K)$ where, $P(K)$ is a set of subsets of K and L is the factor set which is non-void. Then the soft set (H, C) derived from the parent soft set (Ω, L) over K is defined as a *customized soft set* over K, which satisfies the following conditions:

(i) $\bigcup_{u \in L} \Omega(u) = K$.

(ii) $H(ą_{\alpha\gamma}) = \{x : x = \Omega(u_\alpha) \cap \Omega(u_\gamma) \neq \emptyset, \forall\, ą_{\alpha\gamma} \in C\}$,

where $C = \{ą_{\alpha\gamma} : ą_{\alpha\gamma} = u_\alpha \cap u_\gamma \ \forall\, u_\alpha, u_\gamma \in L\}$.

Definition 3.2 Partial bijective soft set

A customized soft set (H, C) over K is represented to be a *partial bijective soft set* $H'(ą_{\alpha\gamma}, ę_{\alpha\gamma})$ over K if the following conditions are satisfied:

(i) $H(ą_{\alpha\gamma}) \cap H(ę_{\alpha\gamma}) = \emptyset$, $\forall\, ą_{\alpha\gamma}, ę_{\alpha\gamma} \in C$, $ą_{\alpha\gamma} \neq ę_{\alpha\gamma}$.

(ii) $\bigcup_{ą_{\alpha\gamma}, ę_{\alpha\gamma} \in C} H'^{(ą_{\alpha\gamma}, ę_{\alpha\gamma})} \subset K$.

Definition 3.3 Absolute partial bijective soft set

A partial bijective soft set is represented to be an *absolute partial bijective soft* set if

$\bigcup_{ą_{\alpha\gamma}, ę_{\alpha\gamma} \in C} H'^{(ą_{\alpha\gamma}, ę_{\alpha\gamma})} = K$.

Example 3.1 Suppose that $U = \{x_1, x_2, x_3, x_4\}$ is the universe set, (F, A) is a soft set associated with U, $A = \{e_1, e_2, e_3, e_4\}$. The mapping of (F, A) is given below:

$F(e_1) = \{x_1, x_2, x_3\}$, $F(e_2) = \{x_2, x_4\}$, $F(e_3) = \{x_1, x_3\}$, $F(e_4) = \{x_2, x_3, x_4\}$. From definition 3.1, $H(a_{12}) = \{x_2\}$, $H(a_{13}) = \{x_1, x_3\}$, $H(a_{14}) = \{x_2, x_3\}$, $H(a_{24}) = \{x_2, x_4\}$, $H(a_{34}) = \{x_3\}$. From definition 3.2, $H'^{(a_{12}, a_{13})}$ and $H'^{(a_{13}, a_{24})}$ are partial bijective soft set and absolute partial soft set, respectively.

Definition 3.4 (Greatest critical limit)

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$\widetilde{\theta}$ is said to be the greatest critical limit (g.c.l) of the decision set D^* if satisfies the following conditions:

(i) $H'^{(\text{ꝗ}_{\alpha\gamma},\text{ꞔ}_{\alpha\gamma})}$ is a partial bijective soft set over the universe set K exists

(ii) $Ð\left(I_k/H'^{(\text{ꝗ}_{\alpha\gamma},\text{ꞔ}_{\alpha\gamma})}\right) = \frac{Number\ of\ non\ identical\ partial\ bijective\ soft\ set\ have\ the\ element\ I_k}{Total\ Number\ of\ non\ identical\ partial\ bijective\ soft\ sets\ exists}$ is exists.

(iii) $0 < \theta_m \leq \widetilde{\theta} \leq Ð\left(I_k/H'^{(\text{ꝗ}_{\alpha\gamma},\text{ꞔ}_{\alpha\gamma})}\right)$, where $Ð\left(I_k/H'^{(\text{ꝗ}_{\alpha\gamma},\text{ꞔ}_{\alpha\gamma})}\right)$ is the decision value of the element I_k over $H'^{(\text{ꝗ}_{ij},\text{ꞔ}_{\alpha\gamma})}$.

Definition 3.5 (Existence of D^*) Change the decision values into a decision set, define $\delta(I_k/(\Omega, L)) = \{1,\ if\ Ð(I_k/H') \geq \widetilde{\theta}\ 0, otherwise$ .... (1)

From (1), the value of $\delta(I_k/(\Omega, L))$ is one, then the element $I_k \in D^*$.

The necessary condition for the existence of a decision set D^* is the cardinality of D^* divides the cardinality of U.

4. An Application of a Partial Bijective Soft Set

Partial Bijective Soft Decision Algorithm 4.1

1. Define a soft set (F, A) with the property $\cup_{e \in A} F(e) = U$.
2. Construct a customized soft set from (F, A) by definition 3.1.
3. Derive the partial bijective soft set by definition 3.2.
4. Apply the decision formula and form a decision set D^* by definition 3.5.
5. Choose the element that satisfies the maximum number of parameters in A.

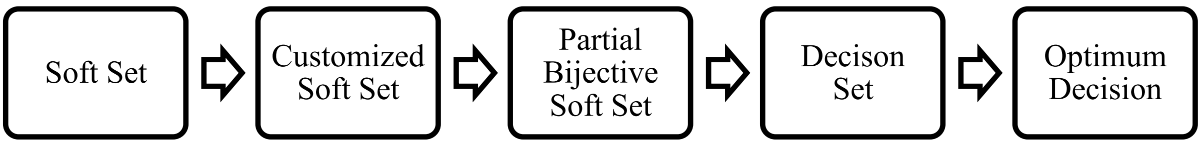

Figure 4.1 Process of the Partial Bijective Soft Decision Algorithm

Example 4.1

Let $K = \{I_1, I_2, I_3, I_4, I_5, I_6, I_7, I_8\}$ be the set of all institutions and

$E = \{e_1, e_2, e_3, e_4, e_5, e_6, e_7\}$ be the parameters for consideration. Here,

$e_1 = academic\ reputation,$

$e_2 = campus\ sources,$

$e_3 = faculty\ expertise,$

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$e_4 = scholarships,$

$e_5 = tuition\ cost\ (Low),$

$e_6 = transport\ facility\ (Location),$

$e_7 = palcement\ training.$

Step 1: Formation of a soft set

Define the soft set (F, A) with the property $\cup_{e_i \in A} F(e_i) = U$, where $A = E$ as follows:

Table 4.1 Tabular Representation of Soft Set (F, E)

E U	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8
e_1	1	0	0	0	1	0	0	1
e_2	0	1	0	0	1	0	0	1
e_3	1	1	1	1	1	0	1	1
e_4	1	1	0	0	1	1	1	0
e_5	0	1	0	0	0	0	0	1
e_6	1	1	1	0	1	1	1	1
e_7	1	0	1	0	1	1	0	1

Step 2: Construction of a customized soft set

From the above Table 4.1,

$F(e_1) \cap F(e_3) = F(e_1) \cap F(e_6) = F(e_1) \cap F(e_7) = \{I_1, I_5, I_8\},$

$F(e_1) \cap F(e_2) = F(e_2) \cap F(e_7) = \{I_5, I_8\},$

$F(e_2) \cap F(e_4) = \{I_2, I_5\},$

$F(e_2) \cap F(e_3) = F(e_2) \cap F(e_6) = \{I_8, I_5, I_2\},$

$F(e_2) \cap F(e_5) = F(e_3) \cap F(e_5) = F(e_5) \cap F(e_6) = \{I_2, I_8\},$

$F(e_1) \cap F(e_4) = \{I_1, I_5\}, F(e_1) \cap F(e_5) = F(e_5) \cap F(e_7) = \{I_8\},$

$F(e_3) \cap F(e_6) = \{I_8, I_7, I_5, I_3, I_2, I_1\},$

$F(e_3) \cap F(e_4) = \{I_7, I_5, I_2, I_1\},$

$F(e_3) \cap F(e_7) = \{I_8, I_5, I_3, I_1\},$

$F(e_4) \cap F(e_5) = \{I_2\},$

$F(e_4) \cap F(e_6) = \{I_7, I_6, I_5, I_2, I_1\},$

$F(e_4) \cap F(e_7) = \{I_6, I_5, I_1\},$

$F(e_6) \cap F(e_7) = \{I_8, I_6, I_5, I_3, I_1\}.$

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By definition 3.1, there exists a customized soft set $H(a_{ij})$ $\forall\, i,j = 1,2, \dots 7$.

(i.e.),

$H(a_{12}) = H(a_{17}) = \{I_5, I_8\}$, $H(a_{13}) = H(a_{16}) = H(a_{17}) = \{I_8, I_5, I_1\}$, $H(a_{14}) = \{I_1, I_5\}$,

$H(a_{23}) = H(a_{26}) = \{I_8, I_5, I_2\}$, $H(a_{24}) = \{I_2, I_5\}$,

$H(a_{25}) = H(a_{35}) = H(a_{56}) = \{I_2, I_8\}$, $H(a_{15}) = H(a_{57}) = \{I_8\}$,

$H(a_{34}) = \{I_7, I_5, I_2, I_1\}$, $H(a_{36}) = \{I_8, I_7, I_5, I_3, I_2, I_1\}$, $H(a_{37}) = \{I_8, I_5, I_3, I_1\}$,

$H(a_{47}) = \{I_6, I_5, I_1\}$, $H(a_{45}) = \{I_2\}$, $H(a_{46}) = \{I_7, I_6, I_5, I_2, I_1\}$, $H(a_{67}) = \{I_8, I_6, I_5, I_3, I_1\}$.

Step 3: Derivation of a partial bijective soft set

$H'^{(a_{12}, a_{45})} = H'^{(a_{15}, a_{24})} = H'^{(a_{24}, a_{57})} = H'^{(a_{27}, a_{45})} = \{I_8, I_5, I_2\}$,

$H'^{(a_{16}, a_{45})} = H'^{(a_{25}, a_{47})} = H'^{(a_{35}, a_{47})} = H'^{(a_{47}, a_{56})} = \{I_8, I_5, I_2, I_1\}$,

$H'^{(a_{14}, a_{15})} = H'^{(a_{14}, a_{57})} = H'^{(a_{15}, a_{47})} = H'^{(a_{47}, a_{57})} = \{I_1, I_5, I_8\}$,

$H'^{(a_{13}, a_{45})} = H'^{(a_{14}, a_{25})} = H'^{(a_{14}, a_{35})} = H'^{(a_{14}, a_{56})} = H'^{(a_{17}, a_{45})} = \{I_8, I_5, I_2, I_1\}$,

$H'^{(a_{14}, a_{45})} = H'^{(a_{45}, a_{47})} = \{I_5, I_2, I_1\}$,

$H'^{(a_{15}, a_{34})} = H'^{(a_{34}, a_{57})} = \{I_8, I_7, I_5, I_2, I_1\}$,

$H'^{(a_{15}, a_{45})} = H'^{(a_{45}, a_{57})} = \{I_8, I_2\}$,

$H'^{(a_{37}, a_{45})} = H'^{(a_{45}, a_{67})} = \{I_8, I_5, I_3, I_2, I_1\}$,

$H'^{(a_{15}, a_{46})} = H'^{(a_{46}, a_{57})} = \{I_8, I_7, I_6, I_5, I_2, I_1\}$.

Step 4: Formation of a decision set

Apply the decision formula defined in Definition 3.4, which gives the decision scores of the institutions listed below: $\forall\, i,j = 1,2, \dots 7$;

$D\left(I_1/H'^{(a_{ij}, b_{ij})}\right) = 0.78$,

$D\left(I_2/H'^{(a_{ij}, b_{ij})}\right) = 0.85$,

$D\left(I_3/H'^{(a_{ij}, b_{ij})}\right) = D\left(I_6/H'^{(a_{ij}, b_{ij})}\right) = 0.07$,

$D\left(I_4/H'^{(a_{ij}, b_{ij})}\right) = 0$,

$D\left(I_5/H'^{(a_{ij}, b_{ij})}\right) = D\left(I_8/H'^{(a_{ij}, b_{ij})}\right) = 0.93$,

$D\left(I_7/H'^{(a_{ij}, b_{ij})}\right) = 0.15$.

By definition 3.5, the decision set of our problem is $D^* = \{I_1, I_2, I_5, I_8\}$. Each element of D^* satisfies the greatest critical limit $\widetilde{\theta}\ at$ 75% level.

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Step 5: Optimum decision

From step 4 and table 4.1, I_5 and I_8 satisfies the maximum number of parameters in A.

Therefore, the best institution for higher studies for a student is: I_5 or I_8.

An alternative decision or second choice is I_2.

Python code for Partial Bijective Soft Decision Algorithm 4.1

```
from itertools import combinations
from collections import defaultdict

U = ['I1', 'I2', 'I3', 'I4', 'I5', 'I6', 'I7', 'I8']
E = ['e1', 'e2', 'e3', 'e4', 'e5', 'e6', 'e7']
# Define soft set F: parameter -> set of institutions
F = {
    'e1': {'I1', 'I5', 'I8'},
    'e2': {'I2', 'I5', 'I8'},
    'e3': {'I1', 'I2', 'I3', 'I4', 'I5', 'I7', 'I8'},
    'e4': {'I1', 'I2', 'I5', 'I6', 'I7'},
    'e5': {'I2', 'I8'},
    'e6': {'I1', 'I2', 'I3', 'I5', 'I6', 'I7', 'I8'},
    'e7': {'I1', 'I3', 'I5', 'I8'}
}
# Step 2: Construct Customized Soft Set H(ei ∩ ej)
def build_customized_soft_set(F):
    H = {}
    for (ei, ej) in combinations(F.keys(), 2):
        key = f"{ei}&{ej}"
        intersection = F[ei].intersection(F[ej])
        if intersection:
            H[key] = intersection
    return H

# Step 3: Derive Partial Bijective Soft Set H'
```

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```
def build_partial_bijective_soft_sets(H):
    partial_sets = []
    keys = list(H.keys())
    for (k1, k2) in combinations(keys, 2):
        if H[k1].isdisjoint(H[k2]):
            partial_sets.append((k1, k2, H[k1].union(H[k2])))
    return partial_sets

# Step 4: Apply decision formula D(Ik/H')
def calculate_decision_scores(U, partial_sets):
    scores = defaultdict(int)
    total_sets = len(partial_sets)
    for inst in U:
        count = sum(1 for _, _, s in partial_sets if inst in s)
        scores[inst] = count / total_sets if total_sets > 0 else 0
    return scores
# Step 5: Create decision set and choose the best institution
def decision_making(scores, theta=0.75):
    decision_set = {inst for inst, score in scores.items() if score >= theta}
    return decision_set
# Run all steps
H = build_customized_soft_set(F)
partial_sets = build_partial_bijective_soft_sets(H)
scores = calculate_decision_scores(U, partial_sets)
decision_set = decision_making(scores, theta=0.75)

# Determine the best institution
if not decision_set:
    print("No institution meets the decision threshold.")
else:
    best_institution = max(decision_set, key=lambda i: sum(i in F[p] for p in F))
# Output Results
print("Decision Scores:")
```

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```
for inst, score in scores.items():
    print(f"{inst}: {score:.2f}")
print("\nDecision Set (θ = 0.75):", decision_set)

if decision_set:
    print("Best Institution for Higher Studies:", best_institution)
    print(f"Reason: '{best_institution}' satisfies the following parameters:")
    satisfied_params = [p for p in F if best_institution in F[p]]
    for param in satisfied_params:
        print(f" - {param}")
    print(f"Total Parameters Satisfied: {len(satisfied_params)}")
# List all non-identical Partial Bijective Soft Sets (H')
print("\nList of non-identical Partial Bijective Soft Sets (H'):")
for idx, (k1, k2, s) in enumerate(partial_sets, 1):
    print(f"H'_{idx} from {k1} and {k2}: {s}")

# Count how many partial H' sets exist
print(f"\nTotal number of non-identical Partial Bijective Soft Sets (H'): {len(partial_sets)}")

# Count how many times each institution appears in H' sets
institution_counts = defaultdict(int)
for _, _, s in partial_sets:
    for inst in s:
        institution_counts[inst] += 1

print("\nNumber of H' sets each institution appears in:")
for inst in U:
    print(f"{inst}: {institution_counts[inst]} times")

# Find alternative institutions (excluding the best one)
alternatives = decision_set - {best_institution}
if alternatives:
    print("\nAlternative Institutions for Higher Studies:")
```

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```
for alt in sorted(alternatives, key=lambda i: scores[i], reverse=True):
    alt_params = [p for p in F if alt in F[p]]
    print(f"- {alt} (Score: {scores[alt]:.2f}, Parameters Satisfied: {len(alt_params)})")
```

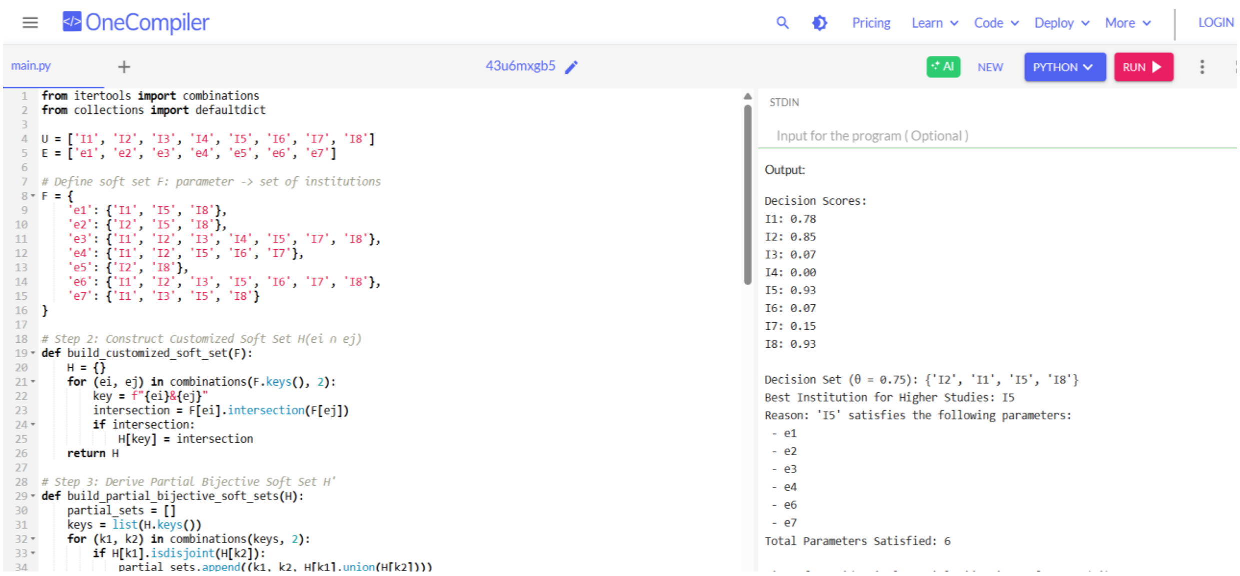

Figure 4.2 Python Coding Output of Partial Bijective Soft Decision Algorithm

Conclusion

This article concludes that an individual student chooses their higher education institution through a partial bijective soft set decision-making process, considering factors like location, affordable fees, and job placement prospects. Therefore, we recommend a partial bijective soft set decision-making process for both students and parents.

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