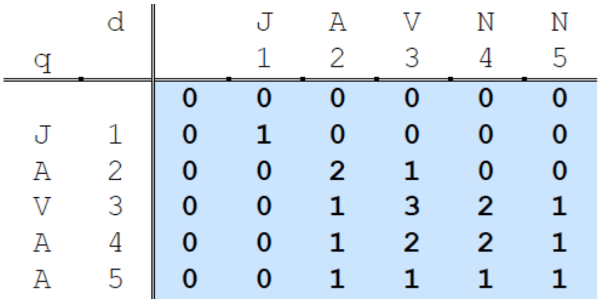
INF281 Exercise 04 solutions

1. **Local alignment with DP**

   The DP algorithm can be used to identify optimal local alignments. Assume the scoring scheme as match: 1, mismatch: -1, and gap penalty: 1.

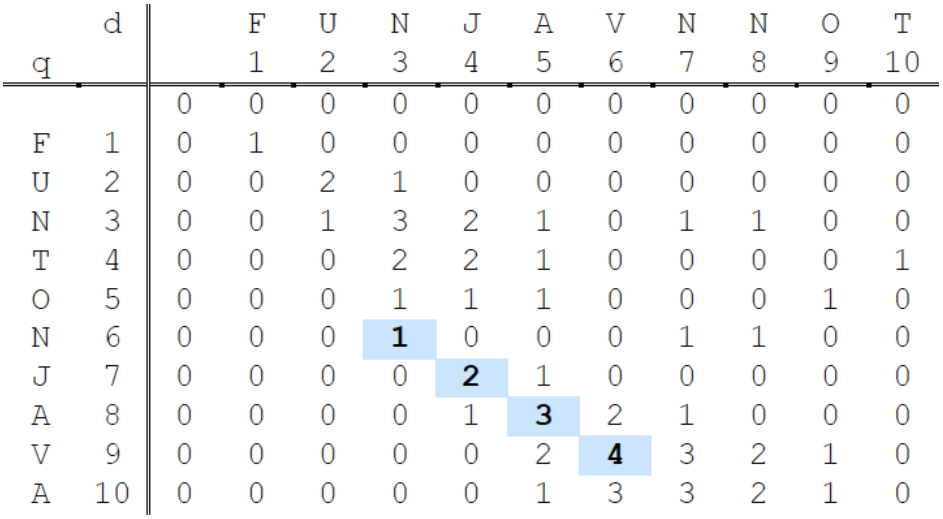
   (a) Complete the DP table to find the optimal local alignment.



	d		J	A	V	N	N
q			1	2	3	4	5
		0	**0**	**0**	**0**	**0**	**0**
J	1	**0**	**1**	**0**	**0**	**0**	**0**
A	2	**0**	**0**	**2**	**1**	**0**	**0**
V	3	**0**	**0**	**1**	**3**	**2**	**1**
A	4	**0**	**0**	**1**	**2**	**2**	**1**
A	5	**0**	**0**	**1**	**1**	**1**	**1**

q: 1 JAV 3
d: 1 JAV 3

   (b) Backtrack from $H_{9,6}$ and write down the local alignment.



	d		F	U	N	J	A	V	N	N	O	T
q			1	2	3	4	5	6	7	8	9	10
		0	0	0	0	0	0	0	0	0	0	0
F	1	0	1	0	0	0	0	0	0	0	0	0
U	2	0	0	2	1	0	0	0	0	0	0	0
N	3	0	0	1	3	2	1	0	1	1	0	0
T	4	0	0	0	2	2	1	0	0	0	0	1
O	5	0	0	0	1	1	1	0	0	0	1	0
N	6	0	0	0	**1**	0	0	0	1	1	0	0
J	7	0	0	0	0	**2**	1	0	0	0	0	0
A	8	0	0	0	0	1	**3**	2	1	0	0	0
V	9	0	0	0	0	0	2	**4**	3	2	1	0
A	10	0	0	0	0	0	1	3	3	2	1	0

Solution:

```
q: 6 NJAV 9
d: 3 NJAV 6
```

2. **Dot matrix**

A dot matrix is one of the simplest methods to identify local alignments.

(a) Fill the table with dots.

	d	F	U	N	J	A	V	N	N	O	T
q		1	2	3	4	5	6	7	8	9	10
F	1	•									
U	2		•								
N	3			•				•	•		
T	4										•
O	5									•	
N	6			•				•	•		
J	7				•						
A	8					•					
V	9						•				
A	10					•					

(b) Identify all segment pairs with at least 3 contiguous dots along diagonals.

Solution:

```
q: 1 FUN 3        q: 6 NJAV 9
d: 1 FUN 3        d: 3 NJAV 6
```

(c) Identify all segment pairs with at least 3 contiguous dots along aniti-diagonals.

Solution:

```
q: 4 TON 6
d: 8 NOT 10
```

3. **N-grams**

N-grams are n-letter words that can be used for database search methods. Create a table of 2-grams for q: ATGCAT.

(a) List all 2-grams of q.

Solution:

```
AT, TG, GC, CA, AT
```

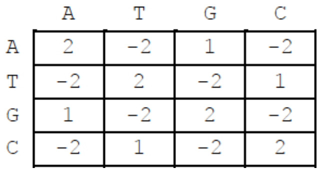
(b) Fill the table with the 2-grams and the corresponding indices of q.

Index of q	2-gram of q
1	**AT**
2	**TG**
3	**GC**
4	**CA**
5	**AT**

4. **Matching n-grams**

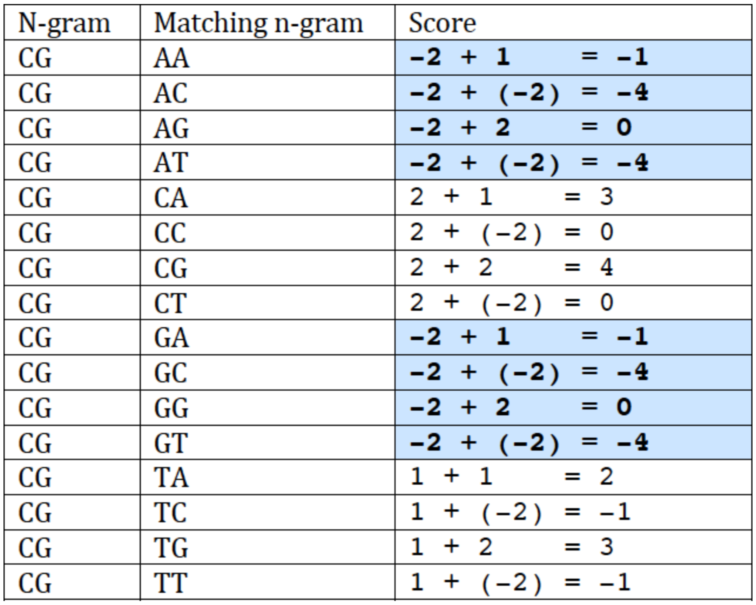
Calculate the scores of the segment pairs between q: CG and all 2-gram permutations of {A, C, G, T}.

Score matrix:



	A	T	G	C
A	2	-2	1	-2
T	-2	2	-2	1
G	1	-2	2	-2
C	-2	1	-2	2

(a) Fill the scores between CG and all its matching n-grams.



N-gram	Matching n-gram	Score
CG	AA	**-2 + 1 = -1**
CG	AC	**-2 + (-2) = -4**
CG	AG	**-2 + 2 = 0**
CG	AT	**-2 + (-2) = -4**
CG	CA	2 + 1 = 3
CG	CC	2 + (-2) = 0
CG	CG	2 + 2 = 4
CG	CT	2 + (-2) = 0
CG	GA	**-2 + 1 = -1**
CG	GC	**-2 + (-2) = -4**
CG	GG	**-2 + 2 = 0**
CG	GT	**-2 + (-2) = -4**
CG	TA	1 + 1 = 2
CG	TC	1 + (-2) = -1
CG	TG	1 + 2 = 3
CG	TT	1 + (-2) = -1

(b) Identify all matching n-grams when the threshold value T is 3.

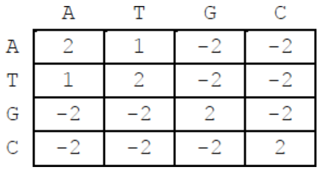
Solution:

```
CA, CG, TG
```

5. **Lookup table for n-grams**

Create a 2-gram lookup table with indices and scores for the sequence q: ATGCAT.

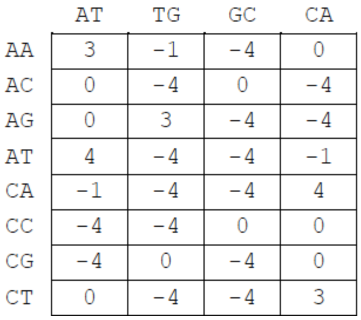
Score matrix:



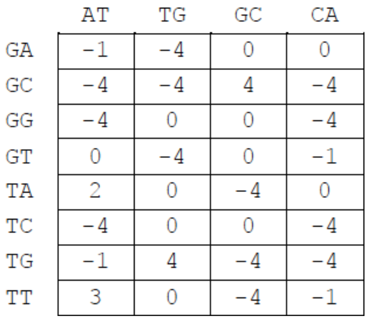
	A	T	G	C
A	2	1	-2	-2
T	1	2	-2	-2
G	-2	-2	2	-2
C	-2	-2	-2	2

T: 3

Pre-calculated scores of all segment pairs:

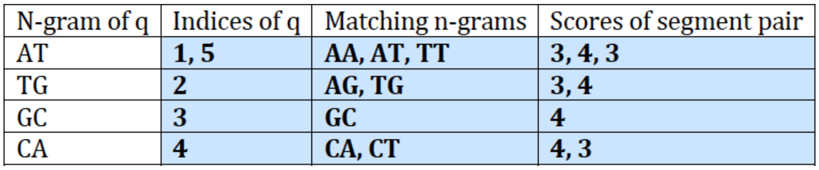


	AT	TG	GC	CA
AA	3	-1	-4	0
AC	0	-4	0	-4
AG	0	3	-4	-4
AT	4	-4	-4	-1
CA	-1	-4	-4	4
CC	-4	-4	0	0
CG	-4	0	-4	0
CT	0	-4	-4	3



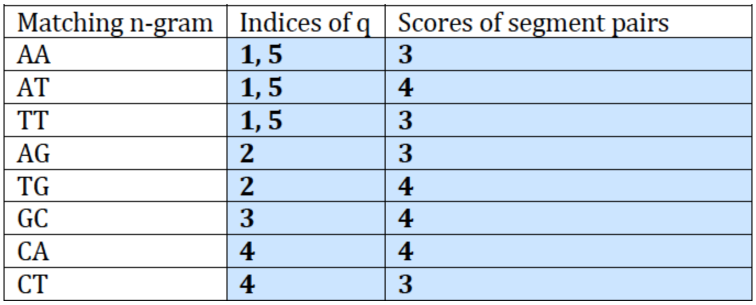
	AT	TG	GC	CA
GA	-1	-4	0	0
GC	-4	-4	4	-4
GG	-4	0	0	-4
GT	0	-4	0	-1
TA	2	0	-4	0
TC	-4	0	0	-4
TG	-1	4	-4	-4
TT	3	0	-4	-1

(a) Fill the table.



N-gram of q	Indices of q	Matching n-grams	Scores of segment pair
AT	**1, 5**	**AA, AT, TT**	**3, 4, 3**
TG	**2**	**AG, TG**	**3, 4**
GC	**3**	**GC**	**4**
CA	**4**	**CA, CT**	**4, 3**

(b) Create a lookup table for the matching n-grams with scores and indices.



Matching n-gram	Indices of q	Scores of segment pairs
AA	**1, 5**	**3**
AT	**1, 5**	**4**
TT	**1, 5**	**3**
AG	**2**	**3**
TG	**2**	**4**
GC	**3**	**4**
CA	**4**	**4**
CT	**4**	**3**

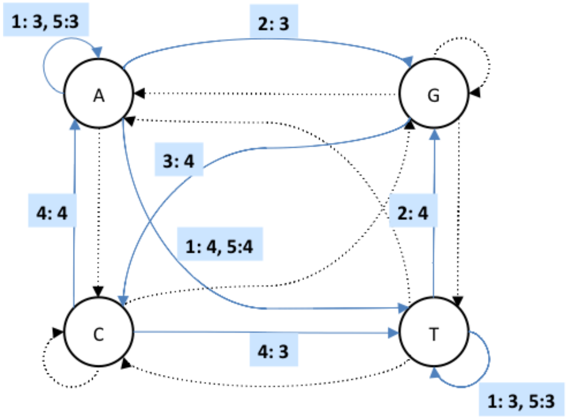
6. **Finite-state machine with 2-grams**

Use the 2-gram lookup table of q = ATGCAT to create a finite-state machine for all potential matching 2-grams.

Lookup table of 2-gram:

Matching 2-gram	**Indices of q**	**Scores of segment pairs**
AT	1, 5	4, 4
AA	1, 5	3, 3
TT	1, 5	3, 3
TG	2	4
AG	2	3
GC	3	4
CA	4	4
CT	4	3

(a) Add indices and scores to the corresponding edges.



(b) Use the finite-state machine to find the matching segment pairs and the scores.

1. d1: TCGGTAA

Solution:

```
q: 1 AT 2    Score: 3    q: 5 AT 6    Score: 3
d: 6 AA 7                d: 6 AA 7
```

2. d2: ATAGC

Solution:

```
q: 1 AT 2    Score: 4    q: 5 AT 6    Score: 4
d: 1 AT 2                d: 1 AT 2

q: 2 TG 3    Score: 3    q: 3 GC 4    Score: 4
d: 3 AG 4                d: 4 GC 5
```

7. **Finite-state machine with 3-grams**

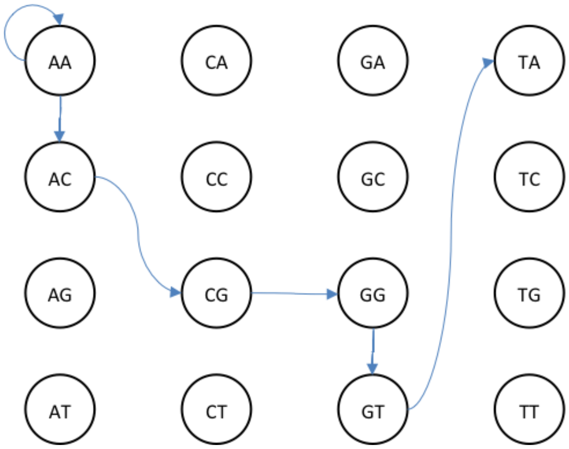
   Add edges to connect nodes to create an overlap graph that can be used as a 3-gram finite-state machine.

   (a) List all 3-grams of AAACGGTA.

   Solution:

   `AAA, AAC, ACG, CGG, GGT, GTA`

   (b) Add edges that correspond to the 3-grams of AAACGGTA.


AA
CA
GA
TA
AC
CC
GC
TC
AG
CG
GG
TG
AT
CT
GT
TT