

# Traversing the $k$ -mer Landscape of NGS Read Datasets for Quality Score Sparsification

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# Next-generation sequencing (NGS)

# The problem with next-generation sequencing

*"In the past two decades, genomic sequencing capabilities have increased exponentially, outstripping advances in computing power and storage."*

- Moore's law predicts that the number of transistors on integrated circuits doubles every 24 months [Moo65].
- Kryder's law predicts that hard drive density doubles approximately every 13 months [Wal05].
- Sequencing output has doubled every 9 months [Kah11].

# How to deal with storage

# The FASTQ format

# Phred quality score

## Definition (Phred quality score)

Let  $P_e$  be the estimated probability that a base call is incorrect. Then we define its *Phred quality score*  $Q$  as

$$Q = -10 \log_{10} P_e.$$

This quantity is encoded in the Sanger FASTQ format as a single byte, where the character '!' represents the lowest quality while '~' is the highest.

# The RQS algorithm in brief

# The DICT algorithm

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**Algorithm 1** DICT

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**Input:**  $C, k, r$

**Output:**  $D$

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1:  $D \leftarrow \{\}$ 
2:  $A \leftarrow [0, \dots, 0] \in \mathbb{N}^{4^k}$ 
3: for  $x \in C_k$  do
4:    $A[x]++$ 
5: for  $x \in [4^k]$  do
6:   if  $A[x] \geq r$  then
7:      $D.append(x)$ 
8: return  $D$ 
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# The MARKMER algorithm

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**Algorithm 2** MARKMER

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**Input:**  $x, D$

**Output:**  $M$

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1: if  $\Delta(x, D) > 1$  then
2:    $M \leftarrow [\text{false}, \dots, \text{false}] \in \{\text{true}, \text{false}\}^k$ 
3: else
4:    $M \leftarrow [\text{true}, \dots, \text{true}] \in \{\text{true}, \text{false}\}^k$ 
5:   for  $y \in D \mid \Delta(x, y) = 1$  do
6:     for  $i \in [k]$  do
7:       if  $x_i \neq y_i$  then
8:          $M_i \leftarrow \text{false}$ 
9: return  $M$ 
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# The MARKREAD algorithm

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## Algorithm 3 MARKREAD

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**Input:**  $\gamma, D$

**Output:**  $\mathcal{M}$

- 1: // Let  $x^a$  be the  $k$ -mer in  $\gamma$  starting at  $a$ .
  - 2: // Cover  $\gamma$  by  $k$ -mers  $\{x^{a_1}, \dots, x^{a_n}\}$ .
  - 3: **for**  $i \in [n]$  **do**
  - 4:    $M^i \leftarrow \text{MARKKMER}(x^{a_i}, D)$
  - 5:    $\overline{M}^i \leftarrow [\text{false}, \dots, \text{false}] \in \{\text{true}, \text{false}\}^{\text{length}(\gamma)}$
  - 6:   **for**  $j \in [k]$  **do**
  - 7:      $\overline{M}_{j+a_i-1}^i \leftarrow M_j^i$
  - 8:  $\mathcal{M} \leftarrow \overline{M}^1 \vee \dots \vee \overline{M}^n$
  - 9: **return**  $\mathcal{M}$
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# The SPARSIFYRQ algorithm

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**Algorithm 4** SPARSIFYRQ

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**Input:**  $\gamma, Q, D, Q_{\text{threshold}}$

**Output:**  $Q'$

- 1:  $Q' \leftarrow Q$
  - 2:  $\mathcal{M} \leftarrow \text{MARKREAD}(\gamma, D)$
  - 3: **for**  $i \in [\text{length}(\gamma)]$  **do**
  - 4:     **if**  $(Q_i > Q_{\text{threshold}})$  **or**  $(\mathcal{M}_i = \text{true})$  **then**
  - 5:          $Q'_i \leftarrow Q_{\text{threshold}}$
  - 6: **return**  $Q'$
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# An example

# Results

# The implementation of DICT

# An alternative implementation

# Bibliography

-  Scott D. Kahn, *On the future of genomic data*, Science **331** (2011), 728–729.
-  Gordon E. Moore, *Cramming more components onto integrated circuits*, Electronics (1965), 114–117.
-  Chip Walter, *Kryder's law*, Scientific American (2005).