Whole exome sequencing analysis pipeline for the discovery of mutations causative of human rare diseases

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Abstract

Recent advances in high-throughput sequencing technologies have made exome sequencing to be an outstanding tool for finding disease associated mutations at a relatively low cost. However, it is a non-trivial task to transform the vast amount of sequence data into meaningful variants to improve disease understanding. Several challenges arise when dealing with this approach, being critical checkpoints the raw read preprocessing, mapping procedure, variant calling and posterior variant selection. A number of computational algorithms and pipelines have been reported for variant analysis, none of them providing a complete strategy from raw data to mendelian analysis results. Here, we present a methodology that spans from SOLiD raw reads processing to mendelian analysis and variant selection, and its application over a set of samples from The Medical Genome Project, which proves the good performance of the applied methodology.

As stated above, the input of the pipeline is an xsq file generated by Applied Biosystem SOLiD 5500 XL sequencers, while the output is the result of variant annotation and mendelian analysis, assuming samples to be derived from a group or a family. A brief description of the steps is provided below:

1. Fasta and qual files generation from xsq files.
2. Duplicated reads removal.
3. BLAT-like Fast Accurate Search Tool v0.7.0a (BFAST) [1] for read mapping.
4. BAM cleaning: duplicated alignments and mismatched reads removal.
5. BAM realignment and SNV calling using the Genome Analysis Toolkit v1.4.14 (GATK) [2].
6. Variant quality filter based on GATK Best Practices V3 and depth filter.

7. Annotate Variation package (ANNOVAR) for variant annotation [3]; SIFT [4] and Polyphen [5] for variant function impact prediction; 1000 genomes [6] and dbSNP [7] for assessment of variant frequency.
8. Mendelian filter of deleterious variants.

The Medical Genome Project (MGP) aims to characterize a large number of rare genetically-based diseases. As a proof of concept, we selected from the MGP a set of affected individuals by several hereditary rare diseases, their healthy relatives and a set of 50 control healthy individuals from Spanish population. The full methodology was run and the results reveal a number of deleterious haplotypes in several genes which could be directly associated with the diseases.

The validation of some of the predicted variants by the pipeline demonstrates the good performance of our methodology analysis. Critical aspects to achieve such good performance are (i) BAM filtering, since an excessive number of mismatches are allowed by BFAST for short reads; (ii) the selection of variant filters and quality thresholds as recommended by GATK Best Practices V3 in combination with a depth threshold allowing high quality calls and (iii) the inclusion of control individuals in the analysis, which is essential since they remove population variants which can disturb the interpretation of the final variant set.

Keywords: NGS analysis pipeline, whole exome sequencing, variant analysis, rare hereditary diseases

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