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# BONAPARTE

## Forensic software for large scale DNA matching

Wim Wiegerinck SMART Research BV, Nijmegen, The Netherlands









## **ABOUT US**

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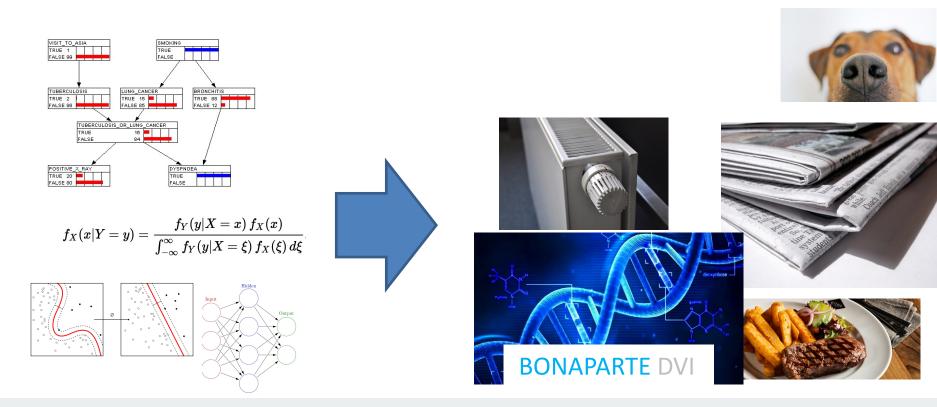






## **Statistical Models and Algorithms**

innovating applications







# ABOUT BONAPARTE



## Netherlands Forensics Institute NFI



SMART







# Identification of unidentified human remains

## **DVI:** Disaster Victim Identification





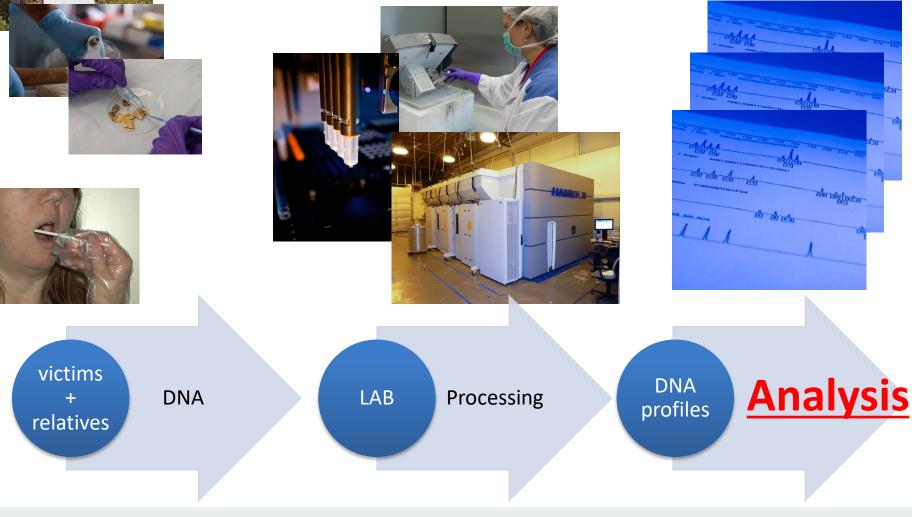




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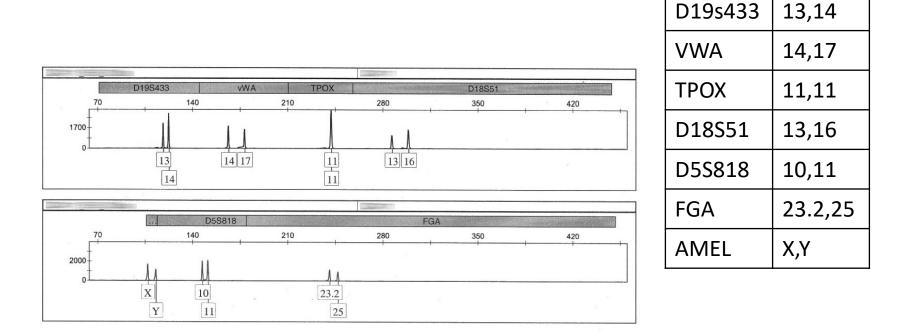


## DNA victim identification workflow





# **DNA** Profile



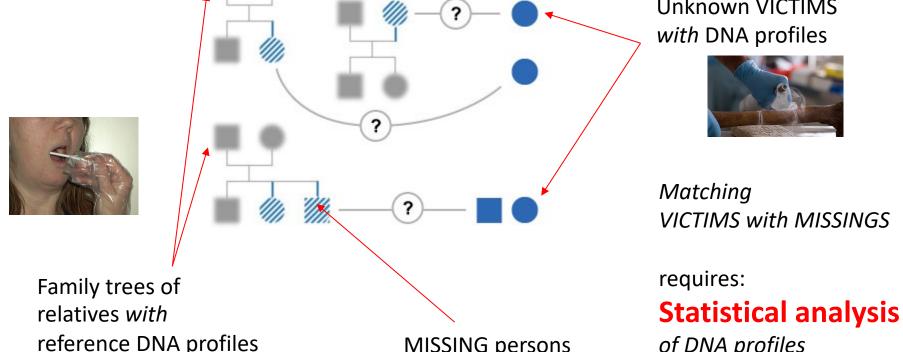
- D19S433 = {13,14} , ...
- Chromosomes come in pairs: one from father, one from mother





# The DVI matching problem:

which victim matches with which family?



**Unknown VICTIMS** with DNA profiles



Matching VICTIMS with MISSINGS

reference DNA profiles

**MISSING** persons without DNA profile of DNA profiles in family trees



- National CBRN/e project
- NFI needed to be prepared for disaster > 500 victims
  - NFI required statistical software for DNA analysis

# BONAPARTE

developed by SMART Research

In close collaboration with **NFI domain experts** and end-users

Forensic Science International: Genetics Supplement Series 2 (2009) 466-468



Forensic Science International: Genetics Supplement Series



#### Research article

Bayesian networks for victim identification on the basis of DNA profiles

C.J. Bruijning-van Dongen<sup>a</sup>, K. Slooten<sup>a</sup>, W. Burgers<sup>b,\*</sup>, W. Wiegerinck<sup>b</sup>

ABSTRACT

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#### ARTICLE INFO

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We have developed software to improve screening and matching routine for victim identification based on DNA profiles. The software, called Napoleon/Bonaparte, uses Bayesian networks for the analysis. It is designed for effective handling of the identification process in case of a large disaster with many victims and can be applied in the missing person program. In this paper we will describe the Bayesian network approach and we will discuss some of the additional features to handle events with many victims. © 2009 Elsevier Ireland Ltd. All rights reserved.

#### 1. Introduction

Bayesian networks are very well suited to model statistical relations of genetic material of relatives in a pedigree [1]. They can be applied in kinship analysis such that whole pedigrees of relatives of the missing persons are used in the screening phase. As a result, correct matches can be found at the costs of much less false biss show wish most and which do not sales and the

#### 2. Bonapartes computational core

Bonaparte's computational core is designed to calculate the likelihood ratio (LR):

 $P(E|H_p)$ LR =(1) $P(E|H_d)$ 



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March 2010: Bonaparte operational

### May 12, 2010: Tripoli, Libya, air disaster 103 victims, 1 survivor

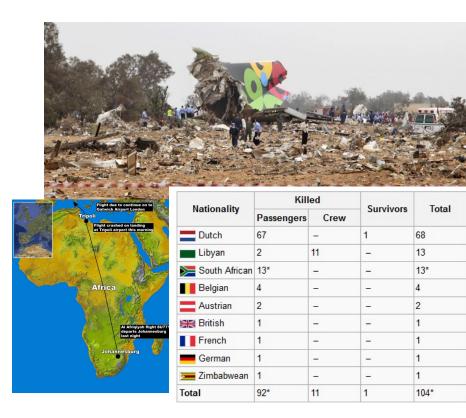
### Identification by NFI

- 57 pedigrees
- 84 missing persons

### Analysis using Bonaparte

84 identifications

The whole project took NFI **26 days** Match computation takes few minutes



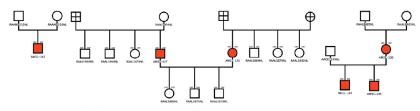


Figure 1. Examples of pedigrees with one, two and three MPs.





# Malaysia Airlines Flight 17 MH17, July 17 2014



- 298 victims
- 6,000+ body parts
- Degraded DNA
- 500+ reference profiles
- 300+ family trees
- 296 victims identified
- Analysis with Bonaparte





Nation 🔶	Number 👻
Netherlands <sup>[f]</sup>	193
Malaysia <sup>[e]</sup>	43
🏝 Australia	27
Indonesia	12
🕌 United Kingdom <sup>[g]</sup>	10
Belgium	4
Germany <sup>[d]</sup>	4
Milippines	3
Canada <sup>[c][34]</sup>	1
🗮 New Zealand	1
Total	298



## BONAPARTE DVI

## Familial search high profile criminal (cold) cases



## Utrecht serial rapist faces maximum jail term of 16 years

Crime Society f 🈏 in 🔊 January 19, 2016





Breakthrough in cold cases involving prostitute murders

CRIME TOP STORIES

ROTTERDAM'S JACK THE RIPPER CAUGHT? ARREST MADE IN DECADES-OLD SERIAL KILLINGS OF 85 PROSTITUTES

y Janene Pieters on April 7, 2017 - 07:39



e more than 30 cases where the DNA database a familial searching technique, a breakthrough this month a 58-year old man was arrested w.A killed two women in Rotterdam in the 1990s. A base for criminal cases based on a DNA profile led to a family member of the suspect. That lead importance to the tracing of the suspect.

> The record of the DNA profile of a family member in the database was the last piece in the family puzzle which the Netherlands Forensic Institute and the cold case team of the Rotterdam Unit police were concentrating on. DNA familial searching performed earlier in this case had failed to generate a match.

However, the DMA expert care across a profile available. The characteristic concerned is seldon found sording to DMA expert Arnoud Kal, 'but there is a 50 percent sing passed down from parent to child so it is not rare within or the Public Prosecution Service, the familial search was re characteristic. It ultimately led to a family member who in any rother or child of the suspect.

II, genealogical and genetic information, the NFI and the cold zee of the person sought - a family tree made up of six it test was performed again later on, it turned out, completely ember had since been entered into the DNA database for on completed the family tree and ultimately provided the police



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### BONAPARTE

### is software for large scale DNA matching

- Client-server structure
  - Platform independent
- User friendly interface via web browse
  - (No need to install client software)
  - Concurrent users
  - Window like structure
- Integrated data base
  - Versioning (audit: who what when)
- Programmable **business rules** 
  - Levels of security and user rights
- Can be **integrated** into **other systems**

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### Australian government

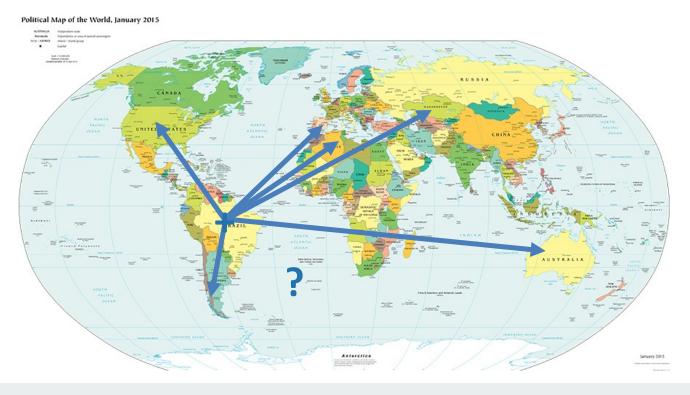
- ACIC (Australian Criminal Intelligence Commission)
  - National information-sharing
  - National Criminal Investigation DNA Database
- DNA investigations across state/territory borders
  - 9 police agencies + other law enforcement
  - About 100 concurrent users
  - Working at different locations
  - business rules, security
- Criminal DNA data base
- Missing persons and unidentified bodies





### **INTERPOL I-Familia**

- I-Familia: global database for identifying missing persons based on international DNA kinship matching
- Victim and families in different member countries
- Runs with Bonaparte: matching to families possible





Wetenschap

### Vietnamese government

- Identification of war victims "project 150"
- Largest victim identification project ever
- **Degraded DNA**
- Remote family members



### Reportage Dna-identificatie Software helpt Vietnam bij megapuzzel

Een enorm project gaat ruim een half miljoen doden uit de Vietnamoorlog aan een naam helpen – en familieleden aan gemoedsrust. De software ervoor is ontwikkeld in Nijmegen.

Dood familielid

is in Vietnam

zeer belangrijk



### **BONAPARTE 2022**





# Conclusions

 Bonaparte: application of AI/Bayesian networks in the real world

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advance in the development of Bayesian networks entailed finding ways to leverage sparseness in the network structure to achieve reasonable computation times.

#### BAYESIAN NETWORKS IN THE REAL WORLD

Bayesian networks are by now a mature technology, and you can buy off-the-shelf Bayesian network software from several companies. Bayesian networks are also embedded in many "smart" devices. To give you an idea of how they are used in real-world applications, let's return to the Bonaparte DNA-matching software with which we began this chapter.

The Netherlands Forensic Institute uses Bonaparte every day, mostly for missing-persons cases, criminal investigations, and immigration cases. (Applicants for asylum must prove that they have fifteen family members in the Netherlands.) However, the Bayesian network does its most impressive work after a massive disaster, such as the crash of Malaysia Airlines Flight 17.

Few, if any, of the victims of the plane crash could be identified by comparing DNA from the wreckage to DNA in a central database. The next best thing to do was to ask family members to provide DNA swabs and look for partial matches to the DNA of the victims. Conventional (non-Bayesian) methods can do this and have been instrumental in solving a number of cold cases in the Netherlands, the United States, and elsewhere. For example, a

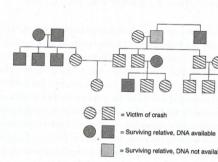
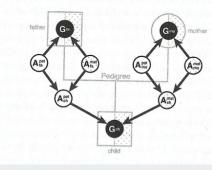


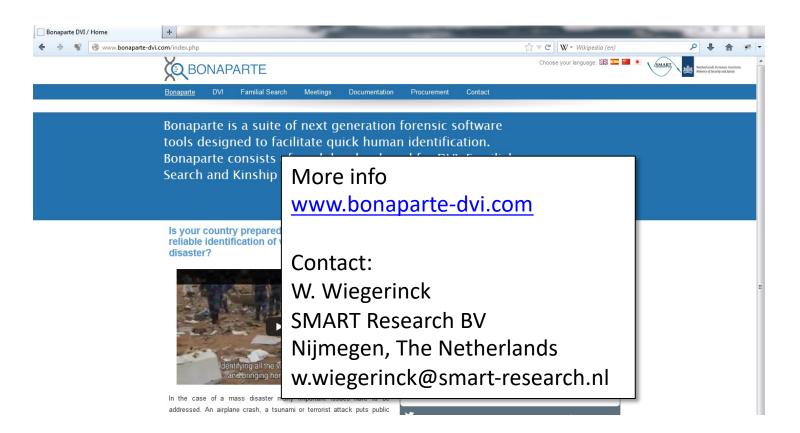
FIGURE 3.7. Actual pedigree of a family with multiple victims is sia Airlines crash. (Source: Data provided by Willem Burgers.)





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### More information?



Bonaparte is proprietary software of SNN, Nijmegen, The Netherlands SMART Research BV a subsidiary of SNN Bonaparte is developed by SMART Research BV and SNN