ECOMEF Project
Eco-design of a mechanized equipment for hardwood harvesting

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FCBA INSTITUT TECHNOLOGIQUE
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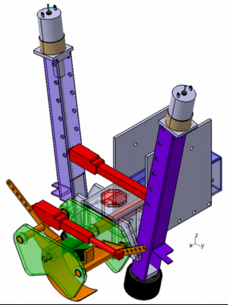
FBR France Bois Régions
INTERNATIONAL PAPER COMPTOIR DES BOIS DE BRIVE
Claude MERCIER Lycée professionnel privé forêt-bois

Harvesting Machine for crooked trees

5th Forest Engineering Conference, September 23-26, 2014, Gerardmer, France



Harvesting Machine for Crooked trees

- FUI ECOMEF
  - Partners
  - Presentation
  - Objectives
- Delimbing
- Conclusion

FUI ECOMEF project: Partners and Funders

Global Budget

3,8 M€

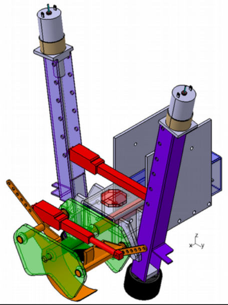
Project partners

- ISI (SME, project leader)
- FCBA
- IFMA / Pascal Institute
- IRSTEA (ex CEMAGREF)
- France Bois Régions (Auvergne Promobois, Interbois Périgord)
- Comptoir des Bois de Brive (France)
- Lycée Claude Mercier
- Accredited by Viameca et Xylofutur clusters

Funders

- FUI French Government
- Auvergne, Limousin and Aquitaine regions
- FEDER Auvergne
- FEDER Limousin
- Clermont Communauté
- General Council of Puy de Dôme
- General Council of Allier
- Brive conurbation

Perriguey / Chebab / Fauroux
IFMA / Institut Pascal



ECOMEF project at IFMA and Pascal Institute

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IFMA : French Institute for Advanced Mechanics

http://www.ifma.fr

- A prestigious **public engineering school** since 1991, part of «Grandes Ecoles» system

- **608** engineer students and **42** engineers by apprenticeship

- **2387** graduated eng. since 1991

- **115 staff**, including 30 academic researchers

- **3 poles**: structures, machines, industrialisation

- **1** Technology Transfer Center

- Favoured relationship with industry

Pascal Institute

http://ip.univ-bpclermont.fr

- UMR CNRS/UBP/IFMA 6602 created in January 2012

- Sciences of engineering and systems

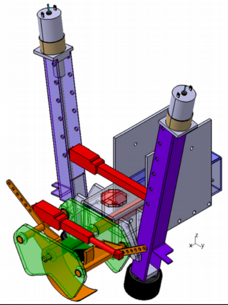
- 130 researchers / 27 engineers and technicians / **115 PhD students**

- **Axis Mechanics, Materials and Structures** (MMS)

  - **Machines, Mechanisms et Industrials Systems** (MMSI)

    - **Mechanisms and robots synthesis**

    - **Behaviour modelling of complex systems in real conditions**



Project FUI ECOMEF (2011-2015)

Harvesting Machine for Crooked trees

Presentation

- FUI : a **pre-competitive project** aimed at developing **industrials products**

Eco-design of a mechanized equipment for hardwood harvesting

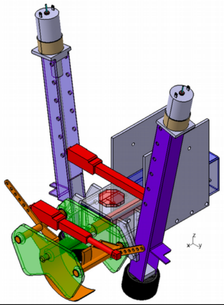
Problem

- Think up **innovative concepts and products** for **mechanized / robotized** hardwood harvesting
- Current equipments are **not suitable for hardwood**
- Lumberjack: a **dangerous** job with poor job prospects
- French forest is growing being **underexploited**

- Energy wood
- Timber

A team for research and development

- **2,5 FTE jobs of engineers at IFMA**
- 2 PhD thesis (innovative design / modelling and simulation)
- One **full-scale demonstrator**
- Several **mono-functional demonstrators**
- A Knowledge Database of hundreds innovating concepts
- Many expected patents



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Project objectives

1. Designing machines that fit brodleaved tree structure

Conifer: linear trunk & fragile branches easy to cut by shock

Broadleaved trees: crooked, numerous strong branches, hardwood

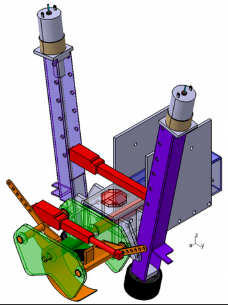
Conifer harvesting machines used onto hardwood: **Breaking risks**

2. Increasing productivity

Conifer : Fir
Time : 1 min 38 sec
9 short-logs + 2 logs
Processed volume : 2,3 m3
Quality : good

Hardwood : Beech
Time : 2 min 14 sec
15 short-logs
Processed volume : 1,1 m3
Quality : poor

Our Goal: design **better harvesting machines** to increase **productivity** of mechanized harvesting heads by **40%** on hardwood trees



Project Technical Objectives

Theme 1 : Harvesting Machines for crooked trees

Existing harvesters are designed for rectilinear trunks: crooked trees have to be managed in several stages

Our goal: feeding crooked trees without stopping or damaging the head

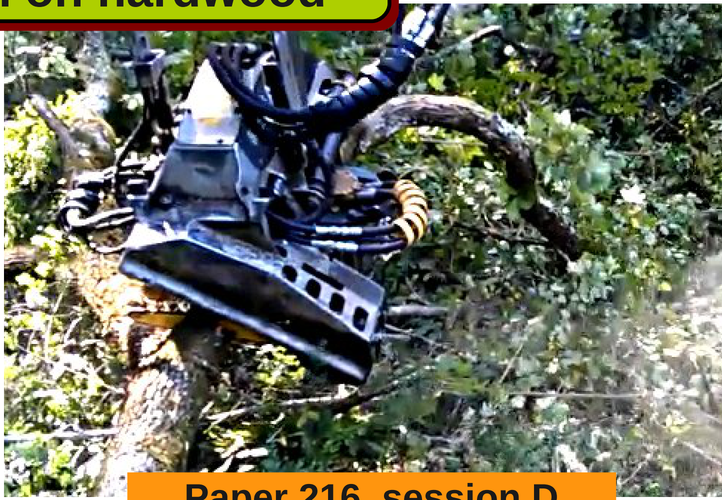
Paper 215, session A

Theme 2 : Delimbing optimization on hardwood

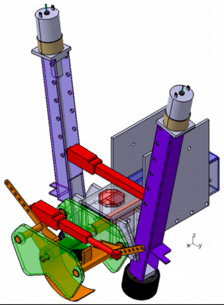
Today, hardwood big branches require to be managed separately by the driver:

- Letting the trunk down
- Catching the branch
- Sawing the branch as a trunk

Our goal: delimbing without stopping or damaging the head



Paper 216, session D

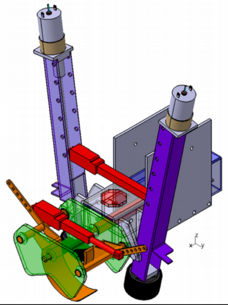


Primary modeling of the system

Harvesting Machine for Crooked trees

Measuring on a real harvesting head

- In association with a lumberjack
- Sensor integration
- Experimental results



Primary modeling of the system

Harvesting Machine for Crooked trees

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Computer modeling

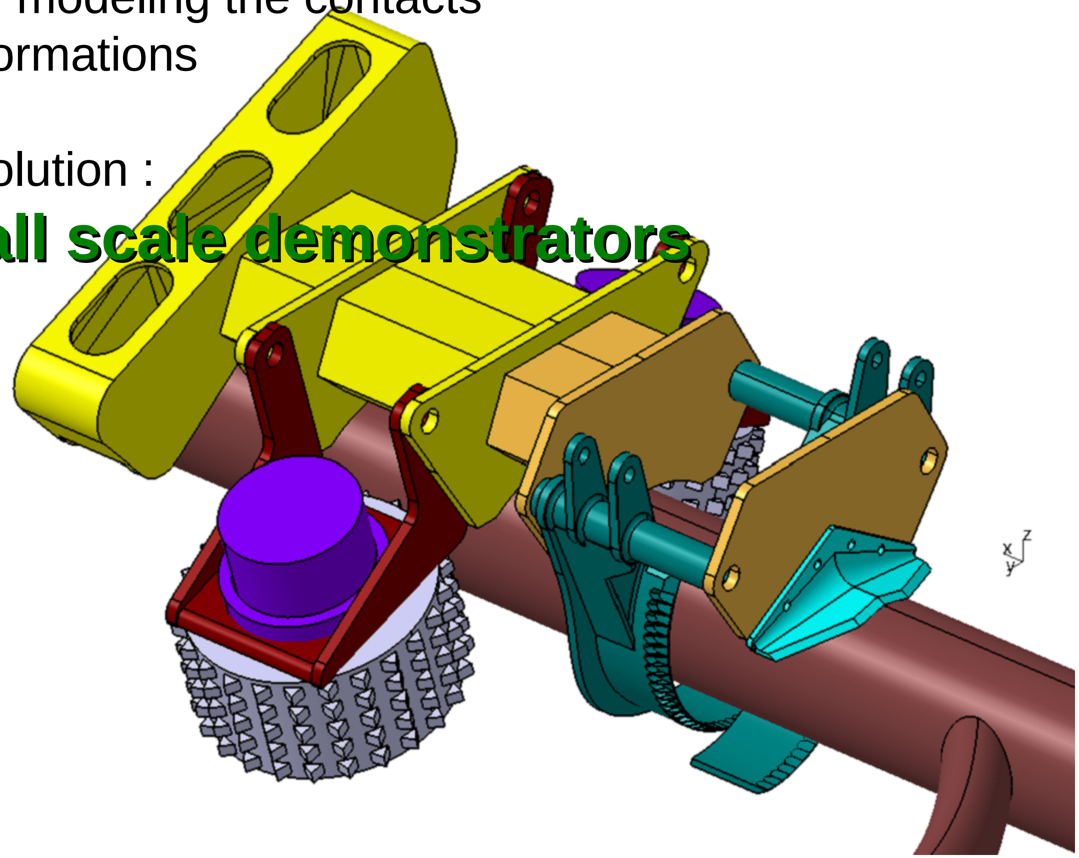
- 3D CAD software : CATIA
- Multibody dynamics simulation : Adams ; Video_8

Problems related to numerical models

- Difficulty of modeling the contacts
- Lack of informations

- Possible solution :

Small scale demonstrators



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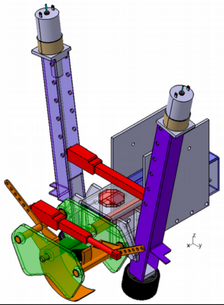

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Small scale demonstrator

Why a small scale demonstrator ?

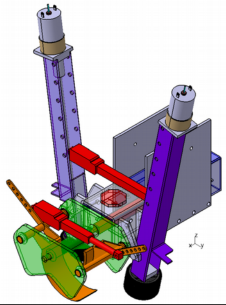
– **Faster** design time
– **Reduced cost** of development
– **Simpler** system than full scale demonstrator

Scale effect consideration

– Use of **dimensionless numbers**
  - Eg : Reynolds, Blake, …
– Difficulty to find suitable scaling laws
  - Numerous parameters
  - Actuators technology

Considered scale

– 1/4 geometric scale



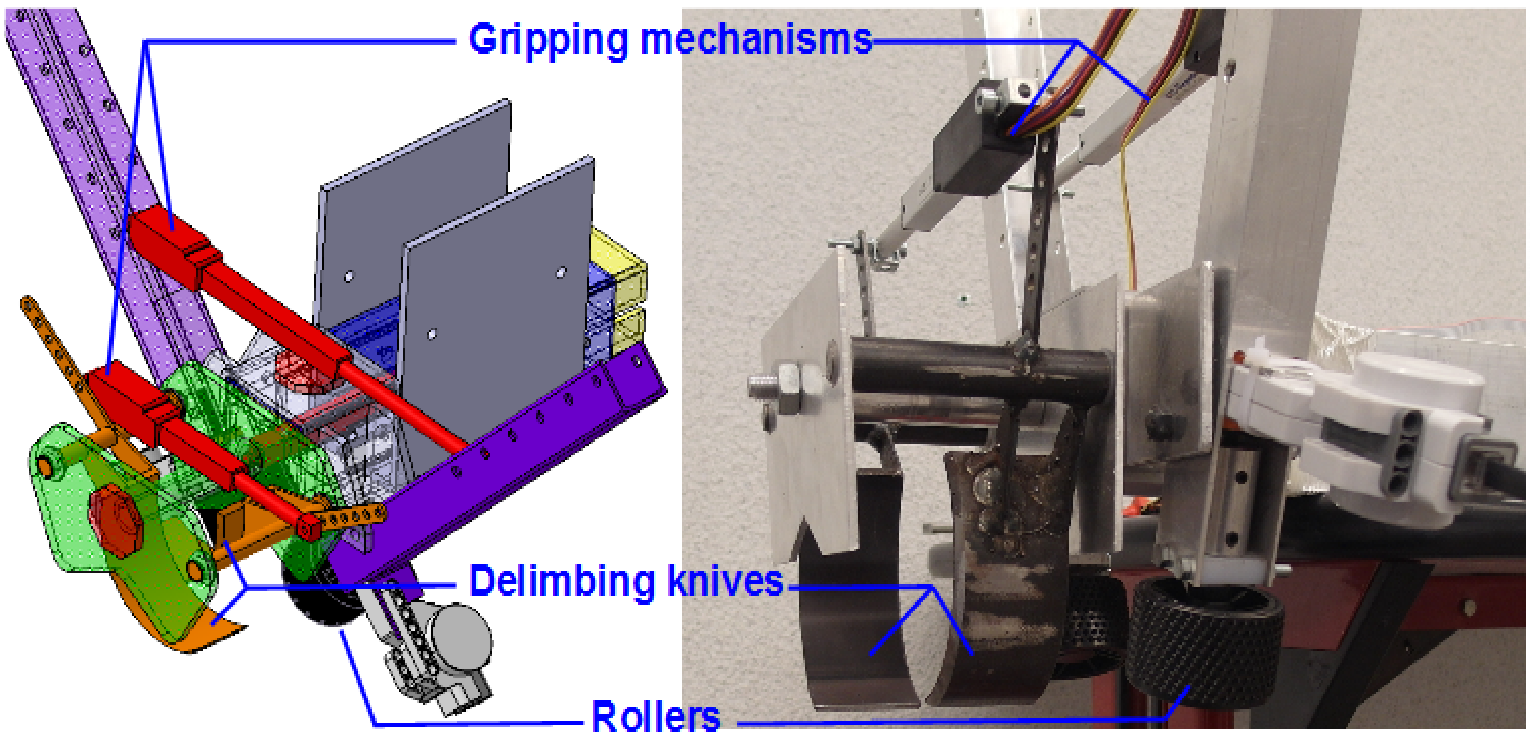
Small scale demonstrator

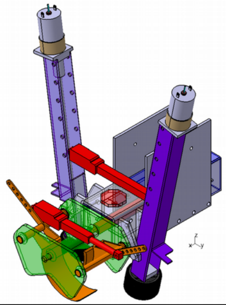
Harvesting Machine for Crooked trees

Purpose

- Reproduce the **feeding action** on a reduced scale
- Study of the influence of **different configurations**
- Find the **set of parameters** allowing curved trunks passage

Used equipments





Tests campaigns

Harvesting Machine for Crooked trees

- FUI ECOMEF
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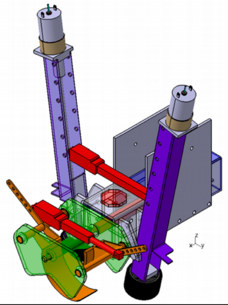
  - Tests
- Conclusion

First campaign

– **Debugging** the demonstrator
– **Dimensioning** the actuators
– Find **limits** of the demonstrator

Second campaign

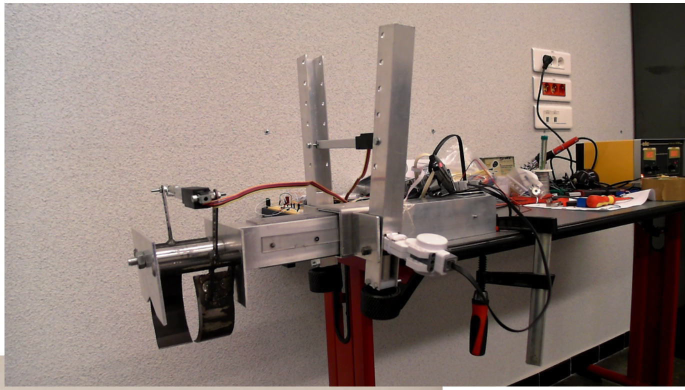
– **Trunk feeding**
  • Main influential parameters
– Effect of **guidance length**
  • Trunk behaviour
  • Conditions for correct passage of curved trunk
– Final correct set of **parameters**

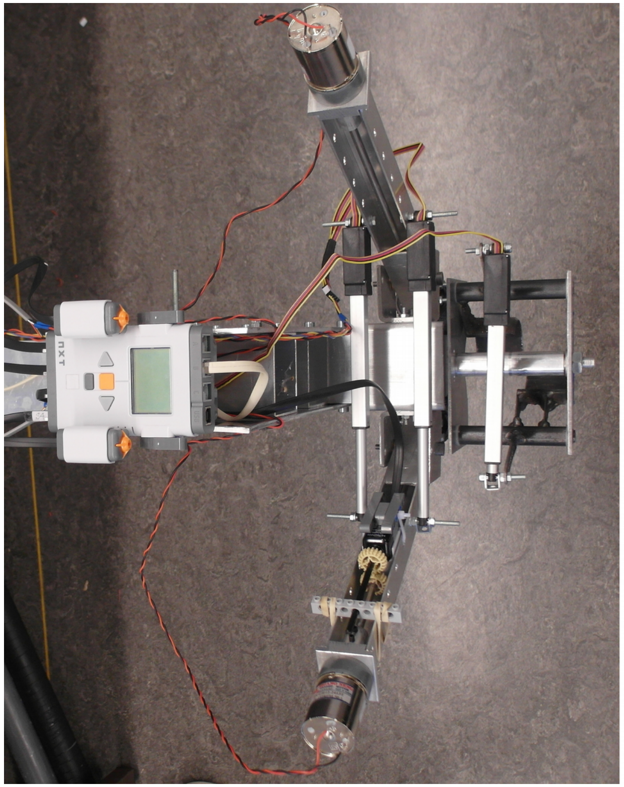


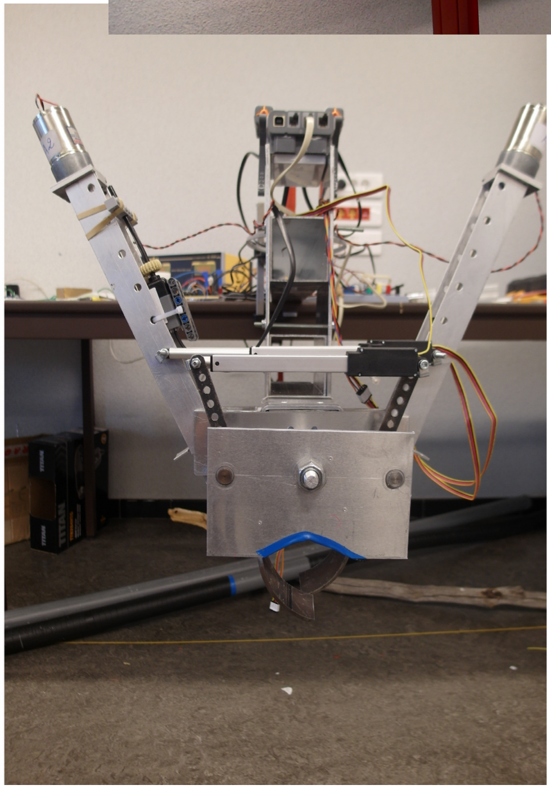
Tests campaigns

First campaign

- Motor power : Video_13.1
  - Changing actuators







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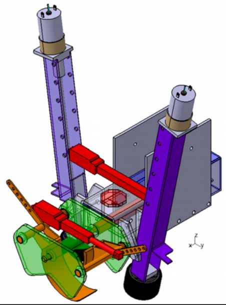

Tests campaigns

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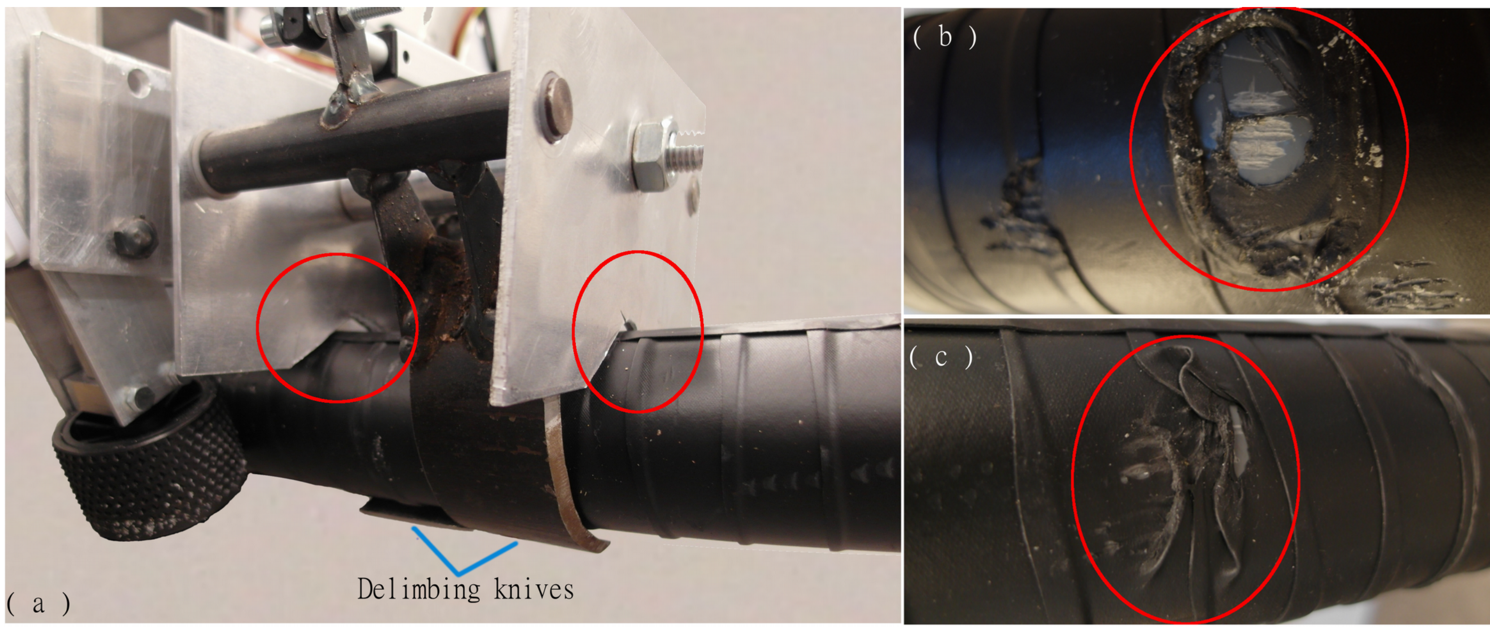
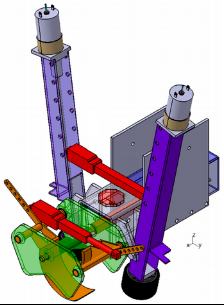
First campaign

– Rubber cover :
  - Traces on the rubber
  - Difficulty of the feeding ; Video_13.2

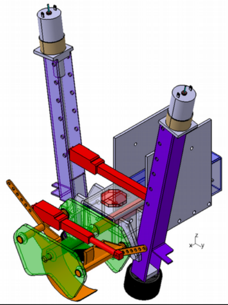




Tests campaigns

First campaign

- Results of the tests :
  - Adjust **actuators**:
    - Change the motors type
    - Doubling linear actuators
  - Modify the **architecture** of the demonstrator
    - Placement of motors and linear actuators
  - Perceive the **limits** of demonstrator:
    - Speed and power of actuators
    - Similarities with the reality
  - Select relevant **real conditions**:
    - Remove the rubber covering

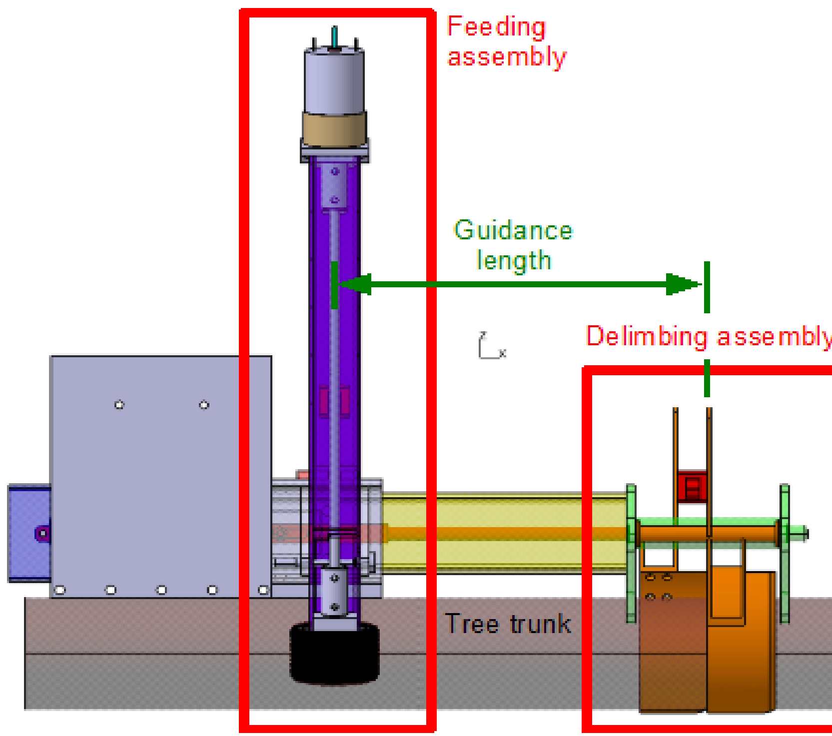


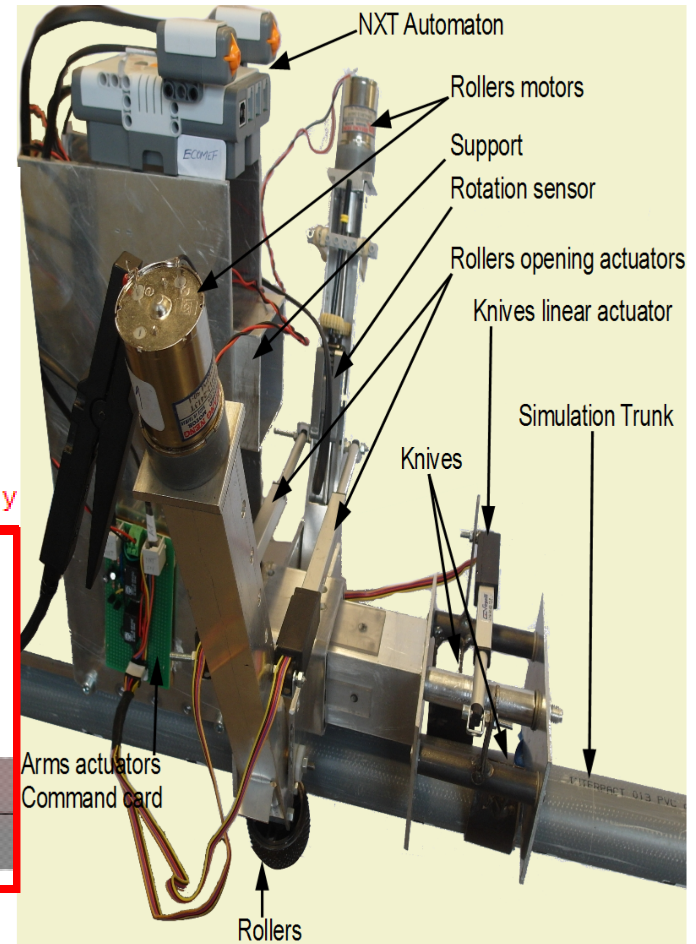
Tests campaigns

Second campaign

Harvesting Machine for Crooked trees

– Complete small scale demonstrator
  - CAD
  - Real





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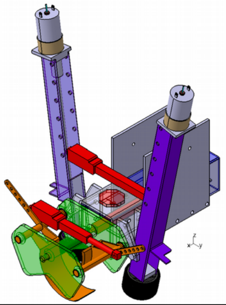


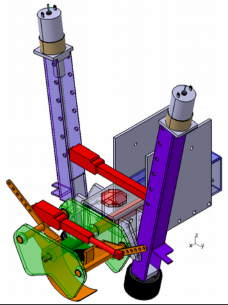
Tests campaigns

Second campaign

- Complete small scale demonstrator
  - CAD
  - Real

- Design of experiment:

For an **initial configuration** of the demonstrator, do
For a **specified experimental trunk**, do
For a **specified openings of rollers and/or knives**, do
For a **guidance length of the demonstrator**, do
Feed the trunk;
End For;
End For;
End For;
End For;



Tests campaigns

Second campaign

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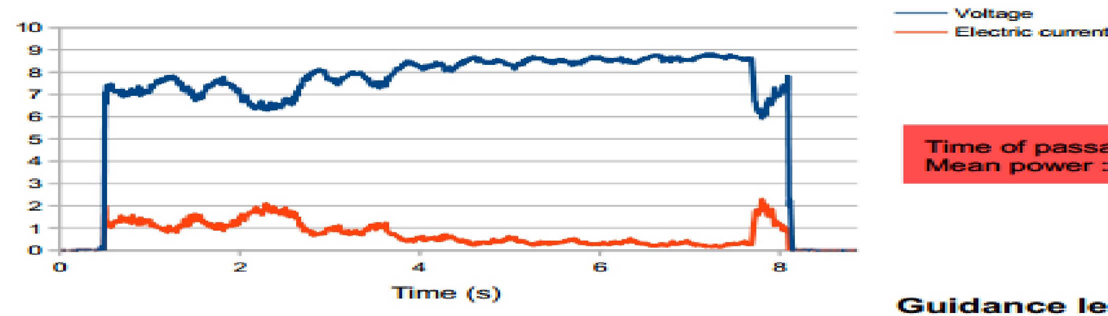
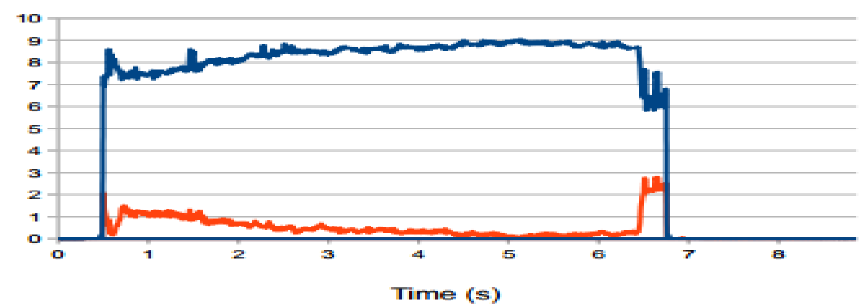
Tests on the effect of the guidance length :



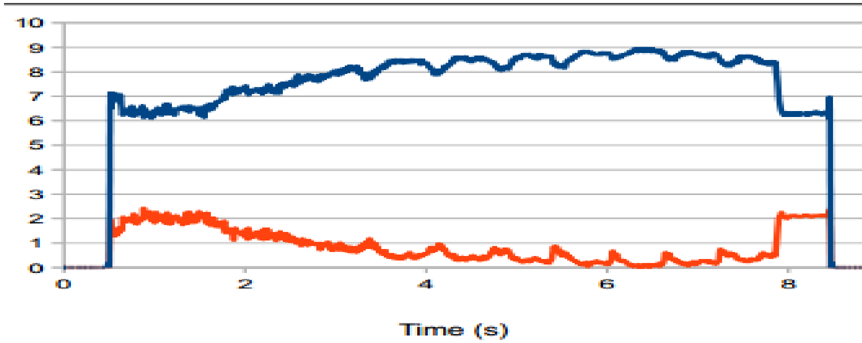
Time of passage : 7,3 s
Mean power : 5,96 W

Guidance length = 50 mm



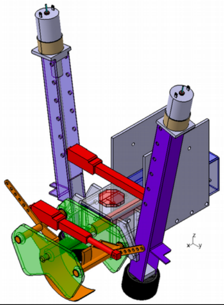
Time of passage : 6 s
Mean power : 4,12 W

Guidance length = 116 mm



Time of passage : 7,45 s
Mean power : 6,51 W

Guidance length = 188 mm



Tests campaigns

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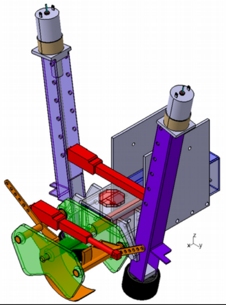
Second campaign

Test on the ability of passing curves:

- Horizontal curves :
  - Example : Video_17.1
    - » Fixed head, with support
    - » Guidance length = 116 mm
    - » Rollers openings = 77 mm
    - » Knives openings = 46 mm
- Vertical curves :
  - Examples : Video_17.3, Video_17.2
    - » Fixed head, with support
    - » Guidance length = 50 mm, 116 mm
    - » Rollers openings = 71 mm, 77 mm
    - » Knives openings = 43 mm, 46 mm



Tests campaigns

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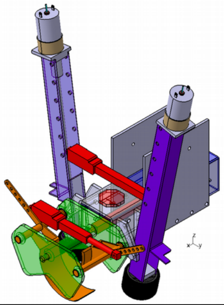
Second campaign

- Results of the tests :
  - Most **relevant parameters** on feeding
    - Rollers openings
    - Guidance length
  - Passing **horizontal curves**
    - Possible with different configurations
    - Confirmation of professional observations
  - **Guidance length** effects
    - Medium length is better for straight trunks
    - Small length tend to help passing curved trunks
  - Passing **vertical curves**
    - Caused damage to the test materials
    - **Impossible with current architectures**

Conclusion

- Existing head do not work

– **- New harvesting heads architectures**



Theme 1 : Conclusion

Harvesting Machine for Crooked trees

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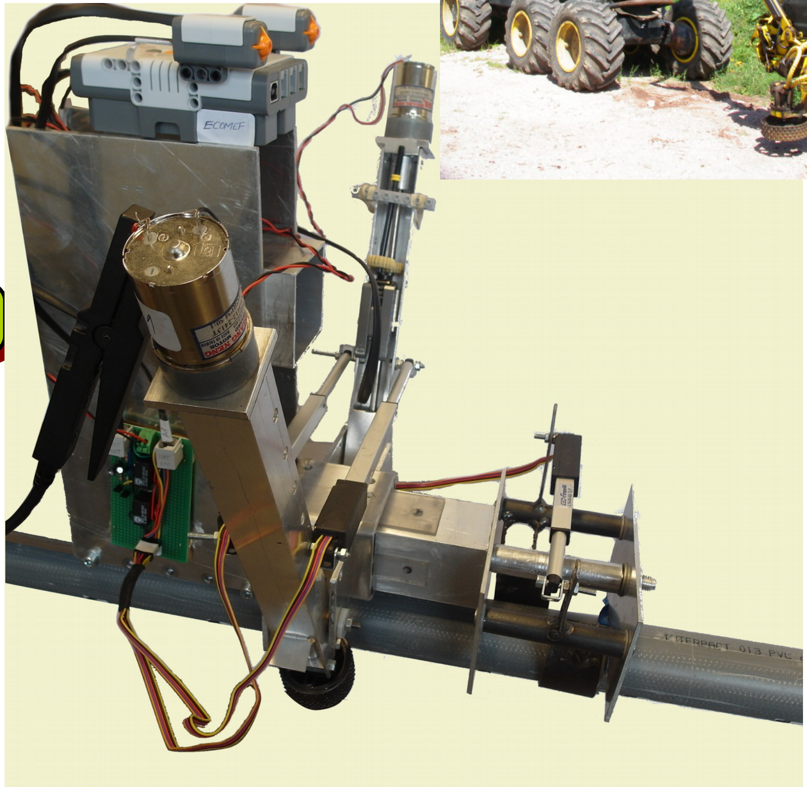
Realised work

- Small scale demonstrator
- Tests campaign allowing better comprehension of real harvesting heads.
- Main parameters:
  - Guidance length
  - Roller opening
  - Curvature orientation

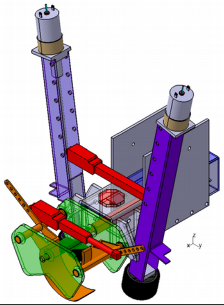


Difficulties

- Scale effect
- Boundary conditions

Results and future work

- Optimal parameters were found
- Existing heads cannot fit vertical curvature
- New head architectures
- Several **patents** pending



FUI ECOMEF - Synthesis

Harvesting Machine for Crooked trees

- FUI ECOMEF
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Engineering

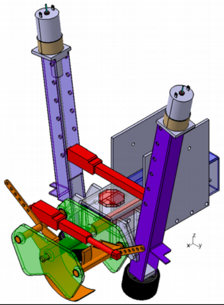
- A team of **researchers, engineers & students of** IFMA-IRSTEA-FCBA-ISI
- ...In association with **wood professionnals**
- Eco-design **of one full scale demonstrator**
- **4 mono-functional demonstrators (test benches)**
- A goal : **+40% productivity** during hardwood exploitation

Research

- Thesis 1 : **innovation methodology** allowing generation and traçability of innovating concepts
- Thesis 2 : two **experimentaly validated models** for feeding and cutting

Results with social impact

- Several pending **patents**
- **Sustainable development** of wood ressource
- Decreasing head **energy consumption**
- **R&D** to design future harvesting machines for a **SME** of Auvergne (ISI)
- **Developing the wood sector** in Auvergne, France and abroad



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Thank you for your attention

Feel free to ask your questions