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Evolutionary Industrial Physical Model Generation

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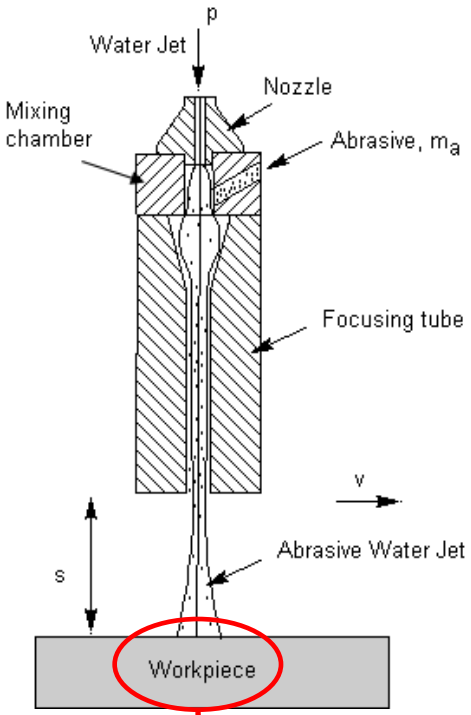
Motivation

Industrial Need: Abrasive water jet cutting machines for milling and shaping materials.

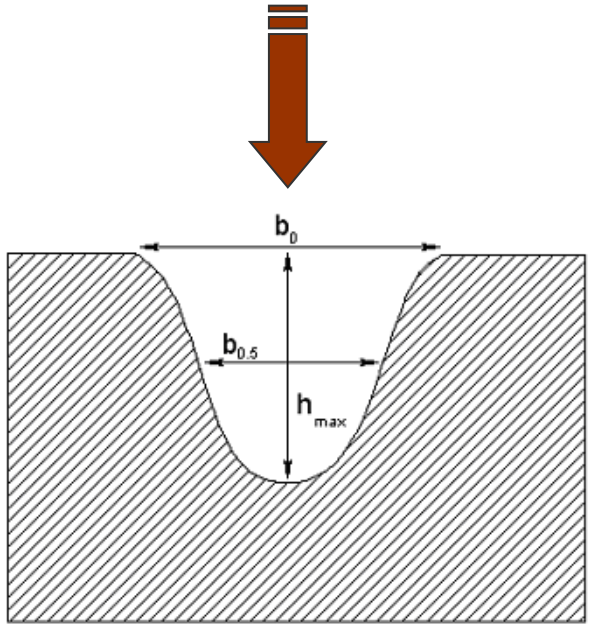
The low cost of the process along with the productivity, the flexibility and its ability to machine any kind of material without heat damage

Obtain a physical model of the milling process

Motivation



Unknown physical model



Kerf Profile Model

$$h=f(h_{max},b_{0.5},r)$$

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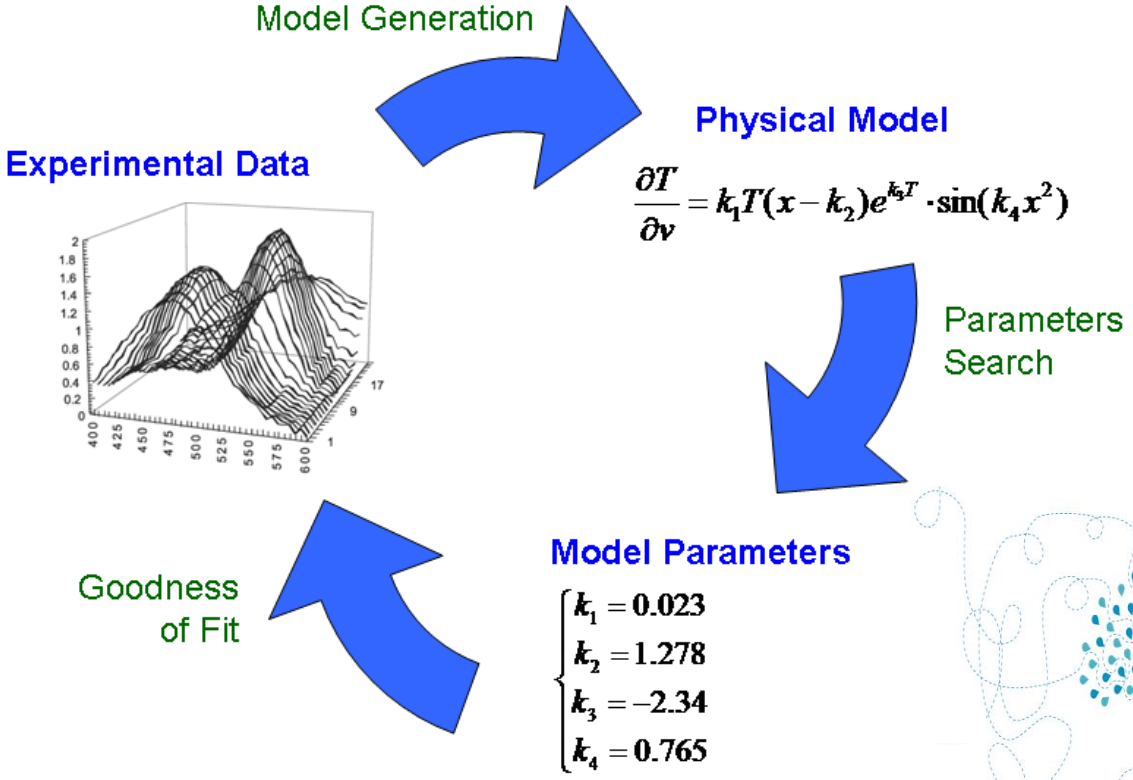
Symbolic Regression (SR)

Discovering a model that fits data



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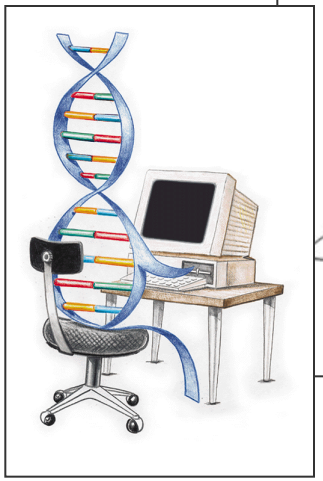
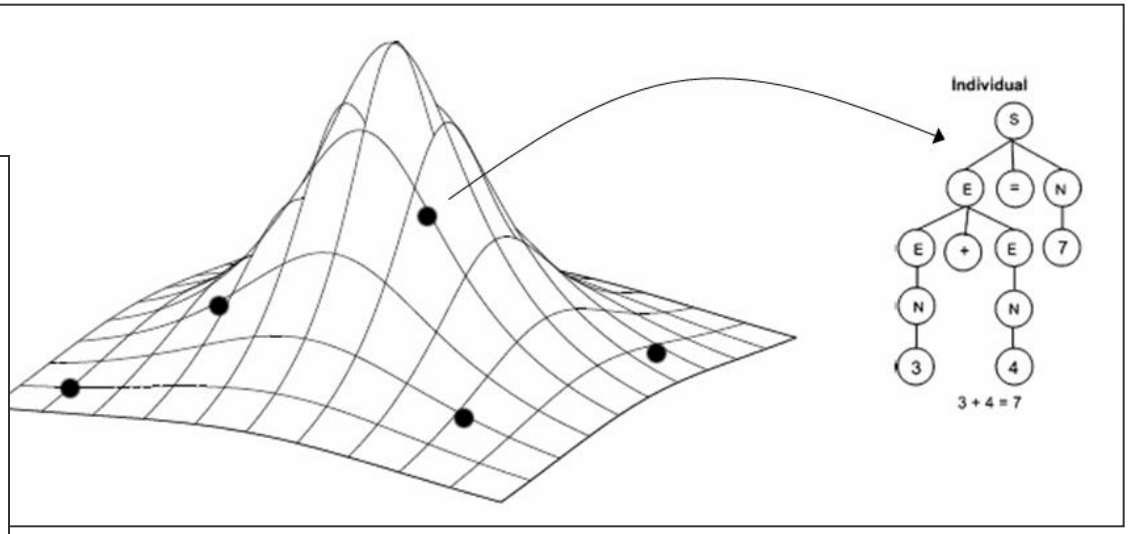
Symbolic Regression

Different Approaches

- Stepwise Regression
- Heuristic data-driven approaches
- Genetic Programming (GP) based approaches





GP Based SR approaches

Advantages:

Free form models (grammar guided GP)

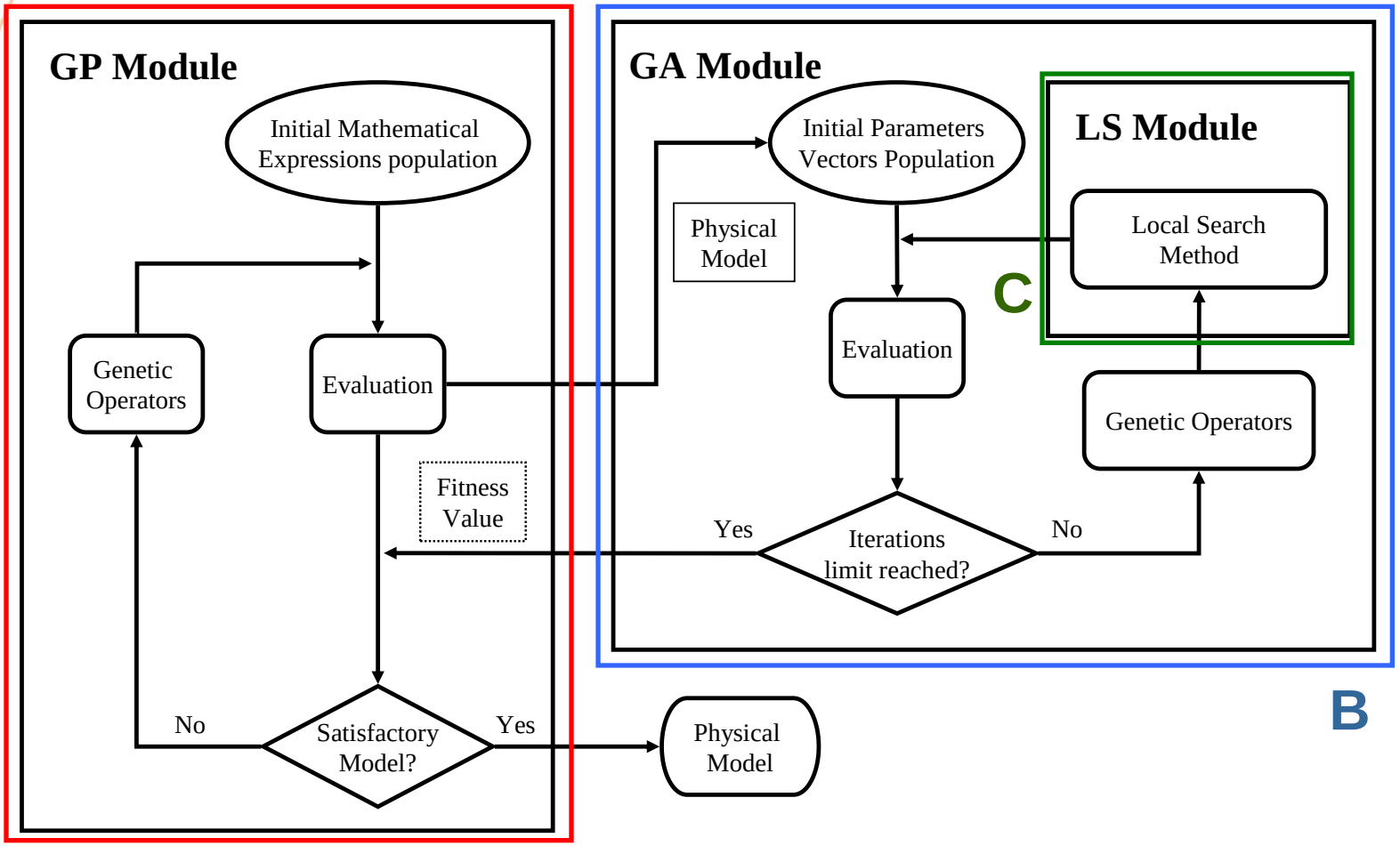
No previuos domain knowledge is needed

Parsimonious criterium

Disadvantages:

Slow process: low exploitation ability (parameters fiiting)

Hybrid Evolutionary Approach for SR



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Context Free Grammar for Mathematical Modelling

$P = \{ S ::= F \ ; F ::= + F F \ ; F ::= - F F \ ; F ::= * F F \ ;$
$F ::= \hat{} \ F F \ ; F ::= e \ F \ ; F ::= k_i \ ; F ::= v_1 \ ; F ::= v_2 \ ; F ::= v_n \}$
$\Sigma_N = \{ S, F \} \quad \Sigma_T = \{ +, -, *, e, \hat{}, t, k_i, v_1, v_2, ..., v_n \}$

Independent variables
Constants
Model parameters
Models: linear, polynomial, exponential, etc.

$$\int_{t_0}^{t_f} k_1 e^t \sin k_2 t^3 dt + \log \left| k_3 \sqrt{kt} \right| + \ldots$$

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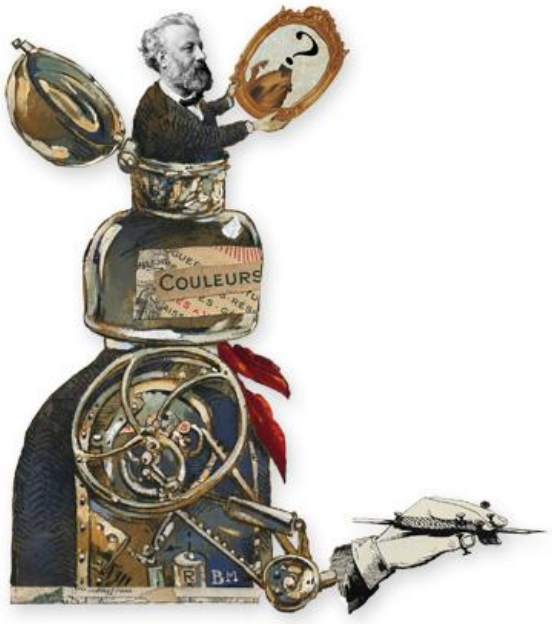
Results

Experimental Data (h_{max},$b_{0.5}$,r): ANOVA

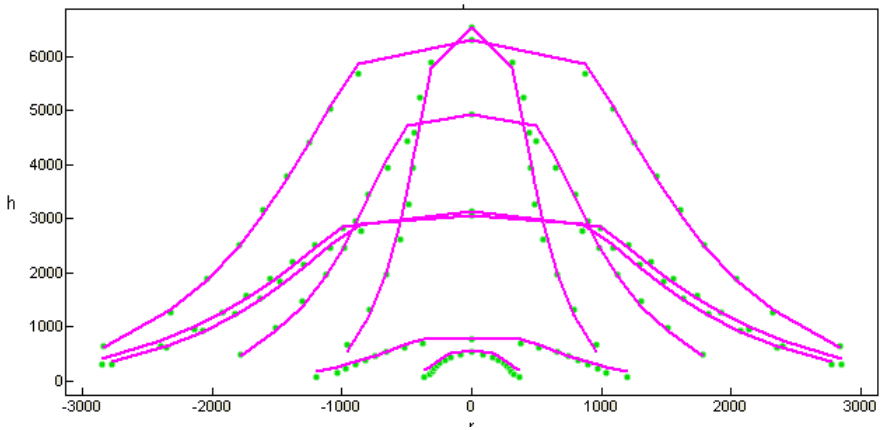
GGGP: Population Size=100, Mutation Probability=0.03

GA:Population Size=50, Iterations Number=10000

LS:Gaussian perturbations

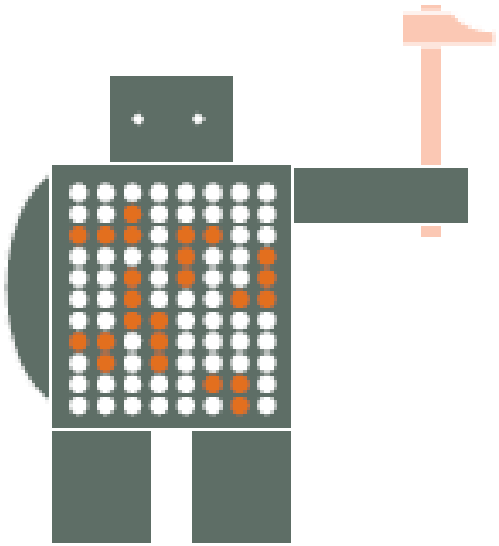


$$f(h_{max}, b_{0.5}, r) = h_{max} - 1.18 h_{max} e^{-\left(\frac{53.33+0.44 b_{0.5}}{r}\right)^2}$$



Conclusions

- A combined evolutionary system has been developed in order to tackle the physical model search problem.
- The system uses a basic mathematical context-free grammar that can be applied to model a great number of physical processes.
- A real world industrial scenario, with the goal of modelling kerf profiles of the AWJ milling process.
- Very promising approach to assist scientists during investigation processes where an unknown physical model is involved.



Thank you!

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