Flow Control Optimization with Computational Fluid Dynamics and Genetic Algorithms

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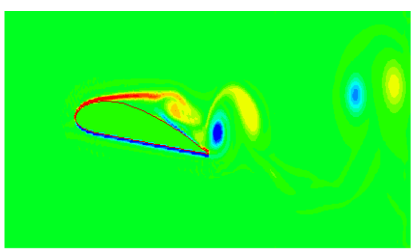
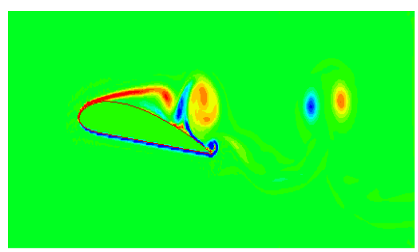
Active Flow Control



No Morphing



Morphing Wing

Parameters: Frequency, Location, Amplitude, Morphing type...

Simulation by V. Katam, R.P. LeBeau, University of Kentucky, Lexington, KY

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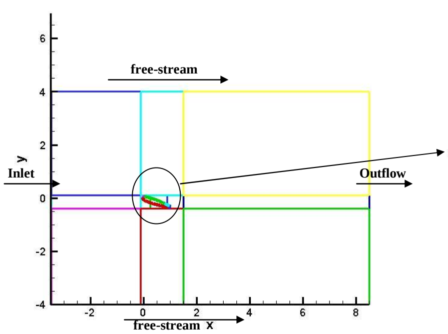
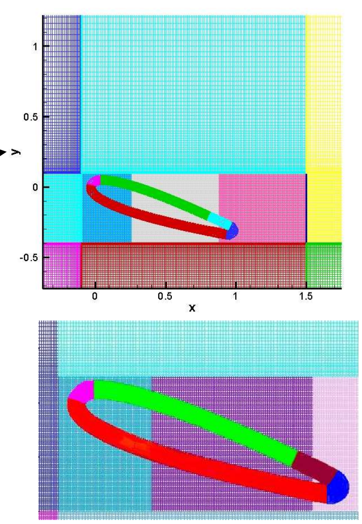
Problem Description

- *Test Case* : Flow over a *NACA0012* airfoil with two suction and two blowing jets.
- *Critical Parameters*: Jet location, amplitude and angle.
- *Genetic Algorithms*: EARND GA and CGA
- *CFD Code* : GHOST

Grid





Flow Conditions:
A_H x A_W = *8c* x *12c*
Jet width = 0.025c
Total grid points: 180,000
Steady state
Total iterations = 35, 000

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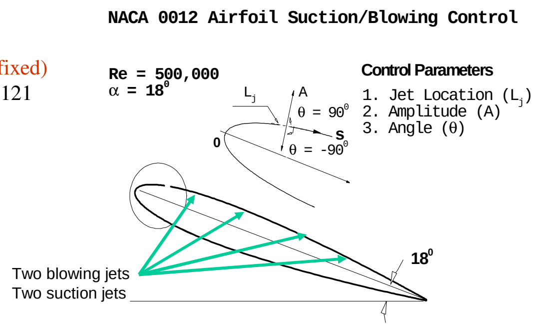
Parameters

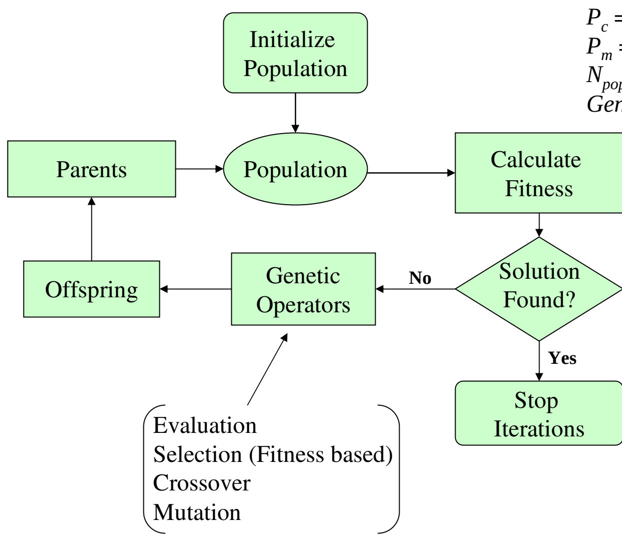
Jet Parameters:

Jet location (L_j): 0.05 – 0.80
Suction jet-1 amplitude (A_{js1}): 0.02121 (fixed)
Suction jet-2 amplitude (A_{js2}): 0.0 – 0.02121
Suction angle-1 & 2 (θ_s): -90º – 0º
Blowing jet-1 & 2: ($A_{b1,2}$): 0.0 – 0.1414
Blowing angle-1&2 (θ_b): 0º – 90º

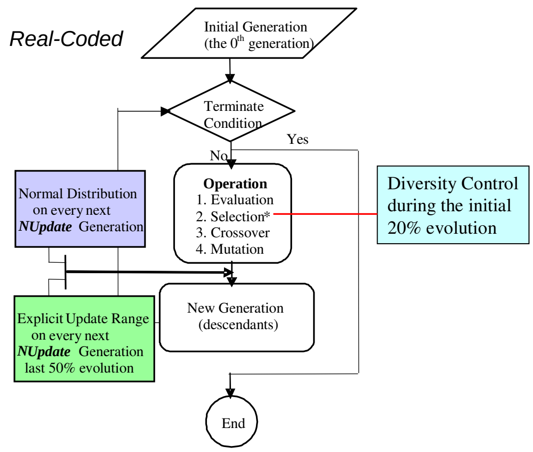


Continuous Genetic Algorithm

P_c = Best 50%
$P_m = 0.15$
$N_{popsize} = 56$
$Generations = 50$



EARND Genetic Algorithm



Explicit Adaptive Range Normal Distribution (EARND)

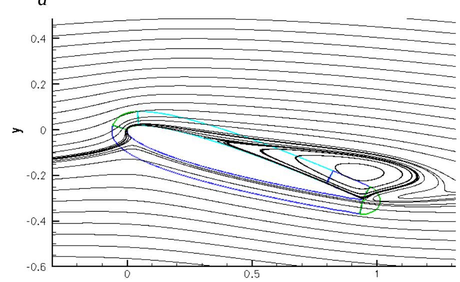
Genetics:

- $P_C = 0.2$
- $P_m = 0.1$
- $NPopSize = 56$
- $NUpdate = 8$
- $Generations = 50$

Fitness

$$(Fit_A)_{\max} = a \cdot C_l / C_{lB} + b \cdot C_{dB} / C_d$$

- C_l - Coefficient of lift
- C_d - Coefficient of drag
- C_{lB} - Baseline lift coefficient
- C_{dB} - Baseline drag coefficient



no jets – baseline case

a & *b* are set such that the *baseline* fitness is 2.0

GHOST

- In-house incompressible CFD code
  - Originally developed by Dr. P.G. Huang
- 2D Navier-Stokes equations solver
- Finite-volume, structured
- 2nd order accuracy in time and space
- QUICK and TVD – for discretization
- Menter's SST two equation turbulence model
- Diffusive terms – central difference
- Pressure – Rhie and Chow

Computation Platform

CFD ME
- 64 nodes
- Xeon 2.66 GHz, 1 GB,
- Dual-switch Gb,15 Gb bridge
- 23 CPU hrs/individual

KFC5
- 47 nodes
- AMD 3200+, 64 Bit, 512 MB
- Single-switch fast Gb ethernet
- 9 CPU hrs/individuals

KFC6
- 47 nodes (24 Intel + 23 AMD)
- AMD 4600+, 64 bit, 1GB ram
- Intel Core 2 Duo (e6400), 1GB
- Single-switch fast Gb ethernet
- 6 CPU hours/individual

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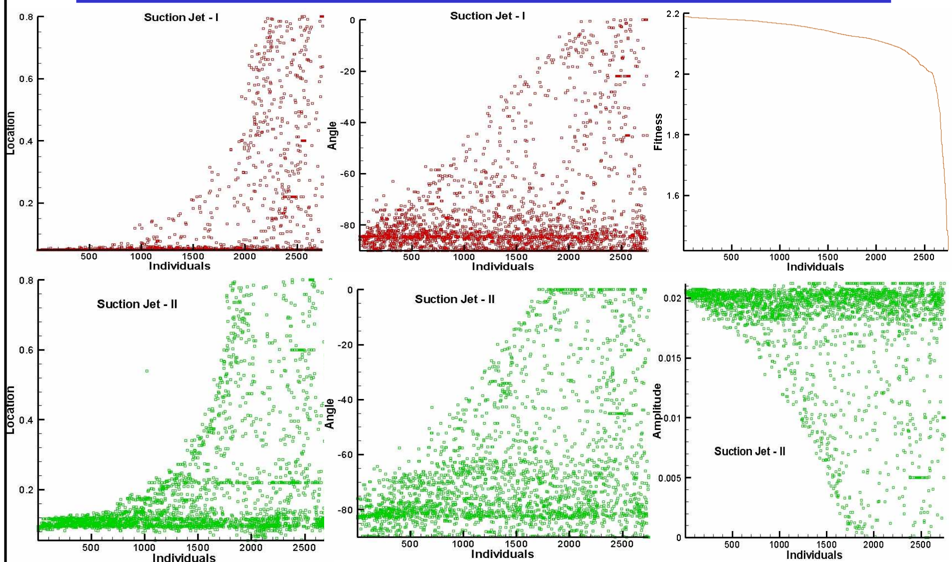
Four Jet Results - CGA



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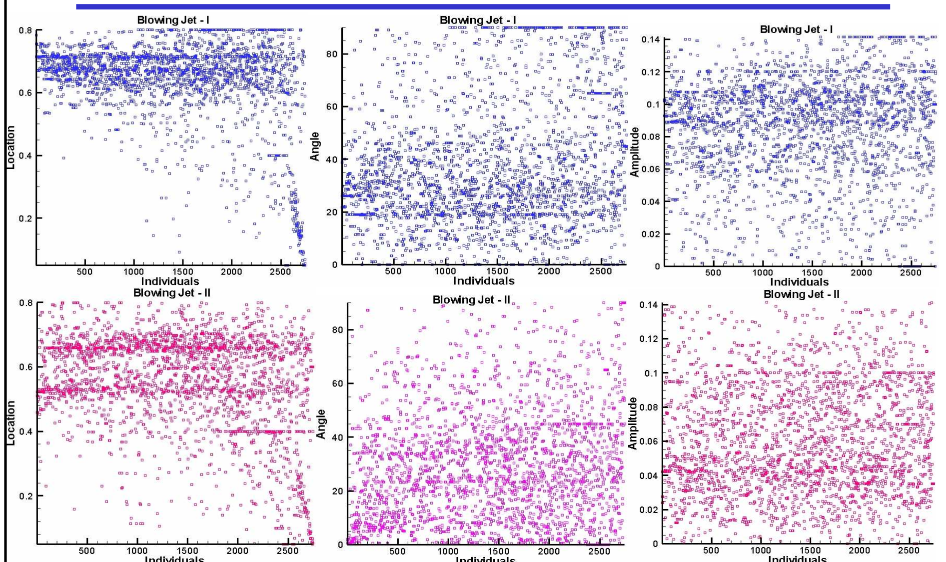
Four Jet Results - CGA



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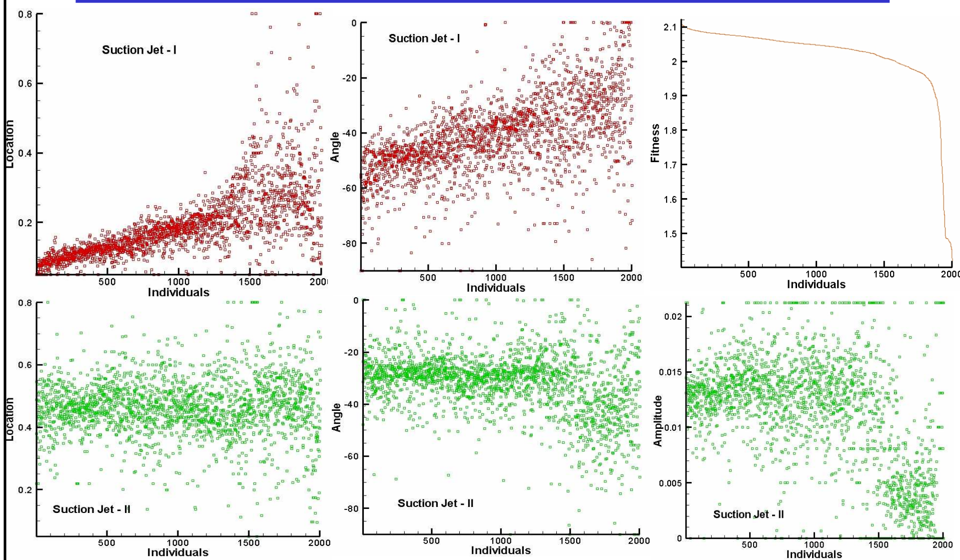
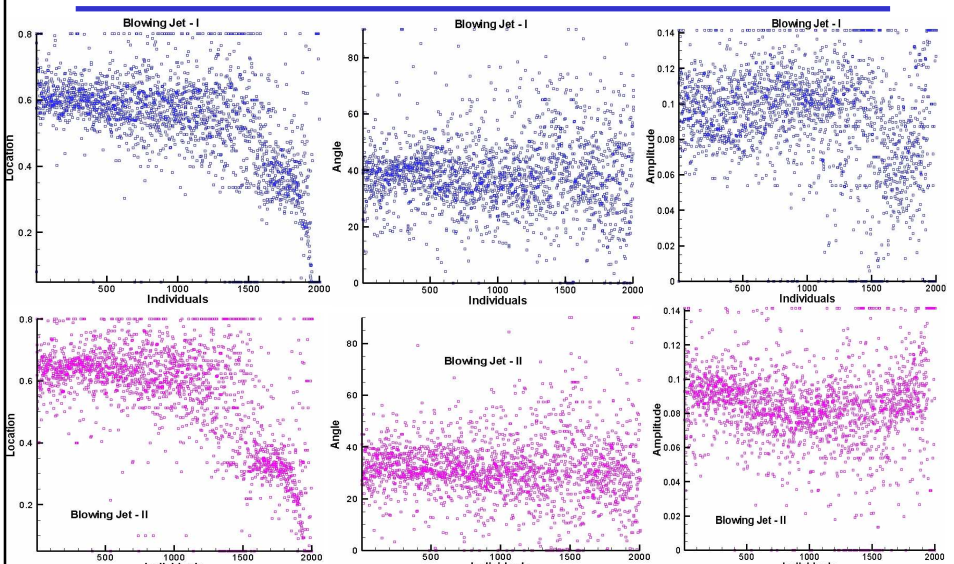
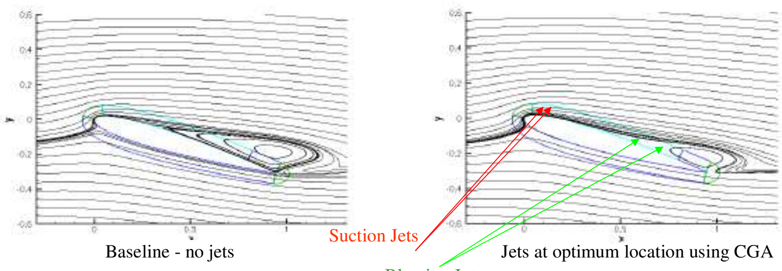
Four Jet Results – EARND GA



Four Jet Results – EARND GA



Final Jet Configuration



Baseline - no jets

Jets at optimum location using CGA

CGA optimum configuration:

L_{s1}	θ_{s1}	L_{b1}	θ_{b1}	A_{b1}	L_{s2}	θ_{s2}	A_{s2}	L_{b2}	θ_{b2}	A_{b2}	C_l	C_d	Fit
0.0500	84.377	0.7149	26.19	0.0928	0.0941	-2.289	0.0206	0.5218	0.597	0.0423	0.9961	0.14966	2.19098

EARND GA optimum configuration:

L_{s1}	θ_{s1}	L_{b1}	θ_{b1}	A_{b1}	L_{s2}	θ_{s2}	A_{s2}	L_{b2}	θ_{b2}	A_{b2}	C_l	C_d	Fit
0.05	-90.00	0.800	90.00	0.1414	0.22	0.00	0.0212	0.6187	45.00	0.1.00	0.9252	0.14836	2.12283

Closing Comments

- Four jet results of both GA approaches drive towards similar jet configuration but CGA performs better in this particular problem.
- Improvement in fitness: CGA ~ 9.5% and EARND GA ~ 6.0%

	C_l	C_d
CGA	11.70% ↑	7.05% ↓
EARND GA	3.75% ↑	7.86% ↓

- Unsteady case: A test case with time dependent synthetic jets is in development.