오픈폼 주요 웹사이트

- **NEXTfoam : www.nextfoam.co.kr**
- OpenFoam Korea Users' community : http://www.okuc.org
- OpenFOAM Foundation : www.openfoam.org
- CFD Online : www.cfd-online.com/Forums/openfoam/
- OpenFOAM Wiki : http://openfoamwiki.net
- Wikki Ltd. : http://wikki.gridcore.se
- Extend-Project : http://www.extend-project.de

- 주 저자
  - Dr. Hrvoje Jasak : Wikki Ltd.
  - Dr. Henry Weller : OpenCFD Ltd. → CFD Direct

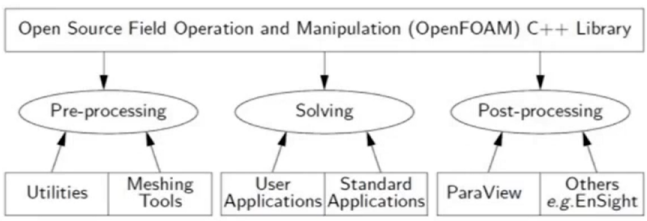
6:00 / 6:19 13

OpenFOAM 기본 강의-1강 (OpenFOAM 소개)

NEXTfoam
チャンネル登録者数 576人
登録済み 20 共有 オフライン

오픈폼의 구성

- C++라이브러리 모음으로 각종 'Standard Application' 을 포함
  - CFD, Electromagnetics, Solid dynamics, Finance 등
- Application은 'Solver'와 'Utility'로 구분
  - Solver는 연속체 역학 계산을 위한 프로그램
  - Utility는 데이터처리 등의 작업에 필요한 프로그램



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오픈폼의 특징

- 어플리케이션(Application)이라고 칭하는 실행파일을 만들기위한 C++라이브러리들의 모음
- 라이브러리들은 해석하고자하는 편미분 방정식과 최대한 유사하게 만들어져 있음
- 소스와 함께 미리 컴파일 된 다양한 어플리케이션이 함께 제공됨

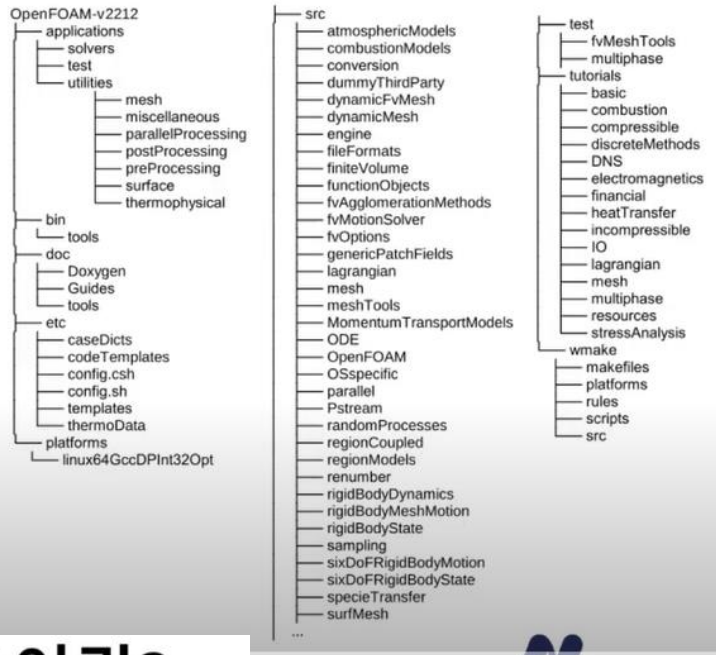
$$\frac{\partial \rho U}{\partial t} + \nabla \cdot \phi U - \nabla \cdot \mu \nabla U = -\nabla p$$

```
solve
(
    fvm::ddt(rho,U) + fvm::div(phi,U) - fvm::laplacian(mu,U) == -fvc::grad(p)
);
```

NEXTFOAM

오픈폼의 구조

- Try the following, a command that enables to view into the directory structure
  - tree -L 2 -d



오픈폼(OpenFOAM)이란?

- OpenFOAM®
  - Open Field Operation And Manipulation
  - Open Source CFD toolbox
- 1989년 영국 Imperial College에서 개발
- 주 저자
  - Dr. Hrvoje Jasak : Wikki Ltd.
  - Dr. Henry Weller : OpenCFD Ltd. → CFD Direct
- 2004년 말 OpenCFD Ltd.에서 v1.0 발표
  - CFD Direct, ESI, FOAM-Extend Project
    - 세 그룹에서 버전 관리
- 2023년 11월 최신 버전
  - CFD Direct(OpenFOAM Foundation): OpenFOAM 11
  - ESI(OpenCFD): OpenFOAM-v2306
  - Foam-extend project: foam-extend-5.0

CAE 분야 주요 공개소프트웨어

- Pre-Processing
  - OpenSCAD
  - Salome
  - GMSH
- Processing (CFD)
  - OpenFOAM
  - Code Saturne
  - SU2
  - SPHysics
  - FDS
- Post-Processing
  - ParaView
  - Visit

Linux (1) – Install WSL

리눅스란?

CLOVA Dubbing

- 리눅스는 1991년 헬싱키 대학의 리누스 토발즈에 의해 만들어진 운영체제
  - 유닉스와 호환되는 공개된 운영체제를 개발
- 다양한 종류의 리눅스 운영체제가 존재
  - Debian, SuSE, Slackware, Gentoo, Red Hat and Mandriva
- 많이 사용되는 리눅스 운용체제인 Ubuntu는 Debian 리눅스 커널을 사용
  - 캐노니컬에서 개발한 컴퓨터 운영체제
  - 사용자 편의성에 많은 초점을 맞추고 있음
  - 남아프리카 공화국의 건국이념인 Ubuntu 'Humanity towards others (다른 사람을 위한 인간애)' 정신에서 가져옴

WSL이란?

CLOVA Dubbing

- Windows Subsystem for Linux
  - Windows에서 별도의 가상머신 없이 바로 Linux 운영체제를 사용할 수 있게 해주는 시스템
- WSL1과 WSL2가 존재
  - 현재는 WSL2를 사용
- WSL2는 실제 리눅스 커널이 탑재됨
  - OpenFOAM을 Windows에서도 사용 가능

OpenFOAM 기본 강의-2강 (리눅스1-WSL 설치)

NEXTfoam
チャンネル登録者数 576人
登録済み
17

Openfoamはlinuxで動くツールのため、
Linux osで使うか？
windowsでlinuxを使得る環境
WSL2を準備して使うか？

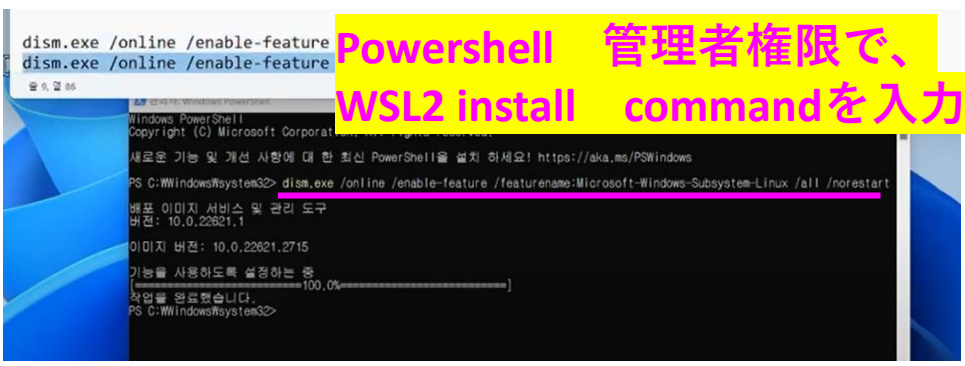
1,006 回視聴 2023/12/12 #강의영상 #openfoam #cfd #오픈폼 #openfoam #cfd #넥스트폼 #강의영상

OpenFOAM 기본 강의 2강 리눅스1-WSL 설치입니다.

wsl 설치 명령어
dism.exe /online /enable-feature /featurename:Microsoft-Windows-Subsystem-Linux /all /norestart
dism.exe /online /enable-feature /featurename:VirtualMachinePlatform /all /norestart
wsl –install -d Ubuntu-20.04
wsl -l -v

wsl 1일 경우
wsl –update
wsl –shutdown
wsl -l -v
wsl –set-version Ubuntu-20.04 2

```
1. Windows 10
        x64 시스템의 경우: 버전 1903 이상, 빌드 18362.1049 이상.
        ARM64 시스템의 경우: 버전 2004 이상, 빌드 19041 이상
2. Windows 11.
```



Powershell 管理者権限で、
WSL2 install commandを入力

1,006 回視聴 2023/12/12 #강의영상 #openfoam #cfd #오픈폼 #openfoam #cfd #넥스트폼 #강의영상

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wsl 설치 명령어
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dism.exe /online /enable-feature /featurename:VirtualMachinePlatform /all /norestart

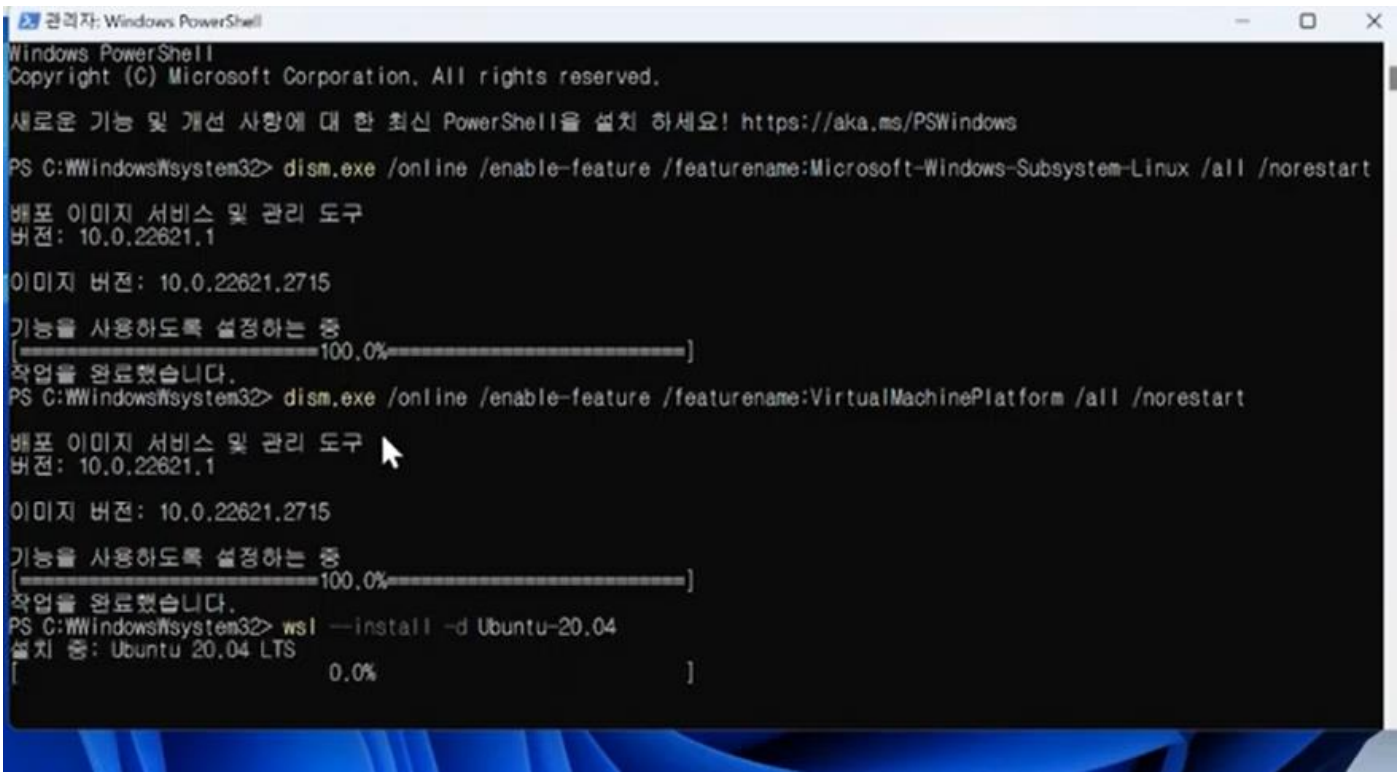
wsl --install -d Ubuntu-20.04

wsl -l -v

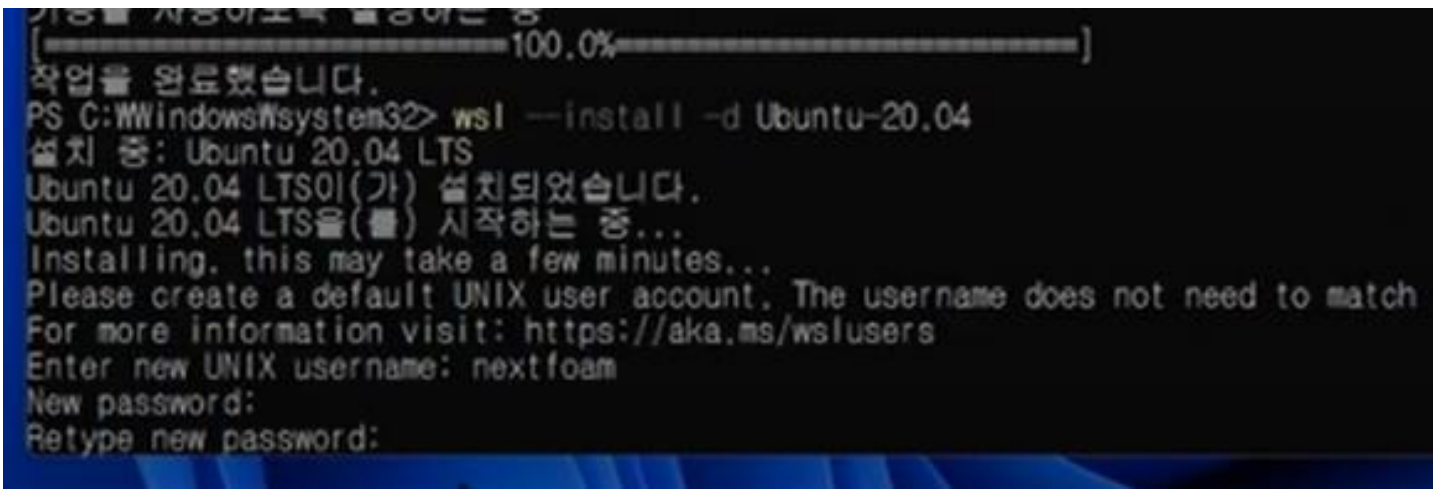
wsl 1일 경우
wsl --update
wsl --shutdown
wsl -l -v
wsl --set-version Ubuntu-20.04 2

PowershellでlinuxのひとつであるUbuntuをinstall

wsl --install -d Ubuntu-20.04

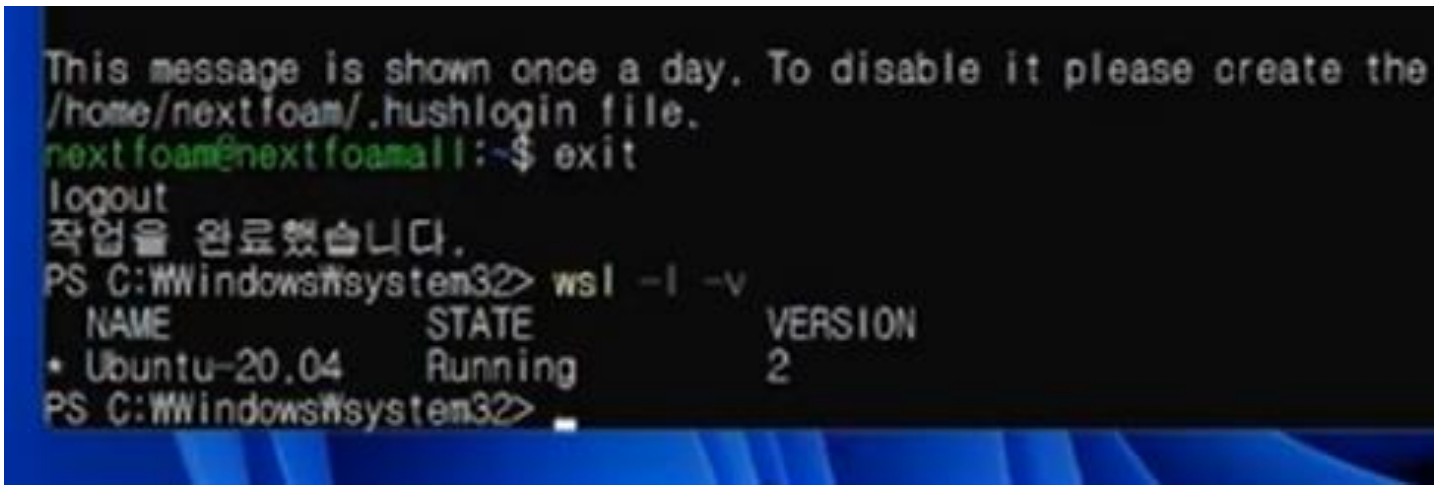


Ubuntuをinstallが終了すると、username とpassword入力画面がでるので、input...

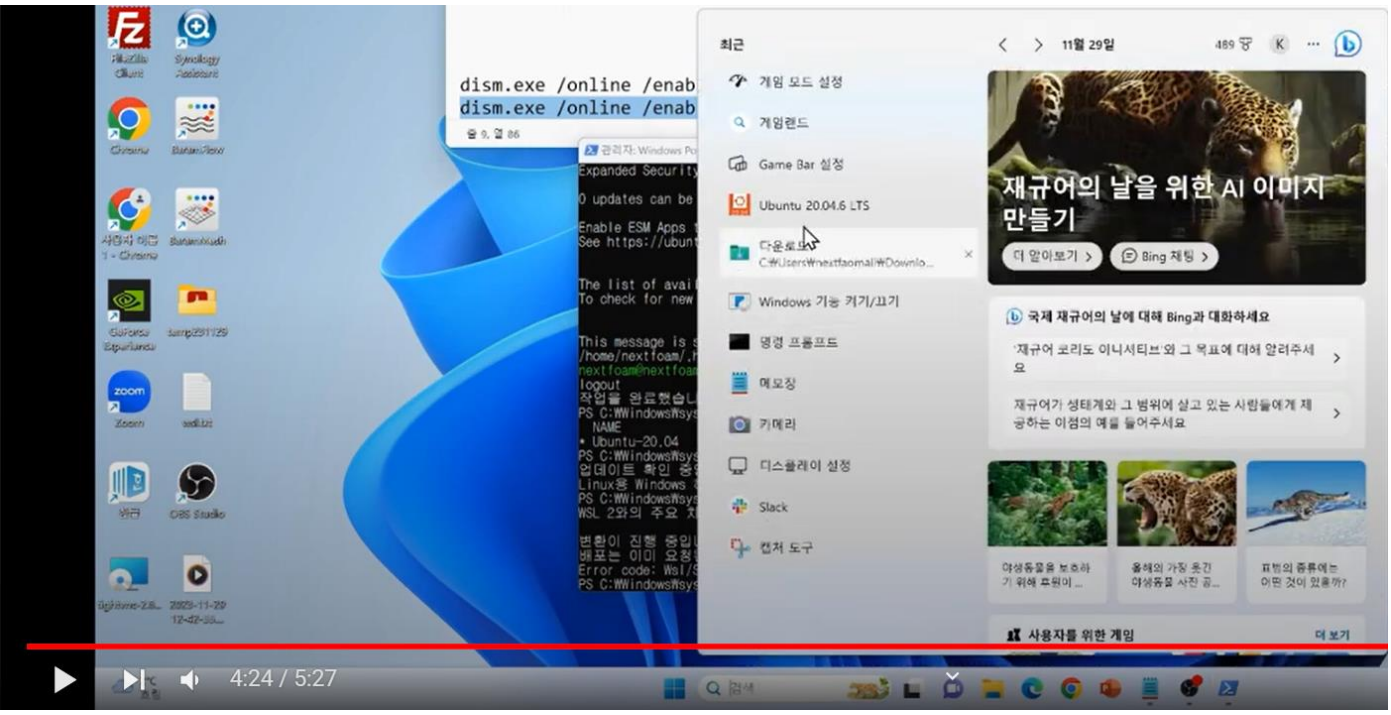


UbuntuからexitLて、
WSLバージョンが２になっているかを確認できると、WINDOWSでLINUX使用環境の準備は完了！

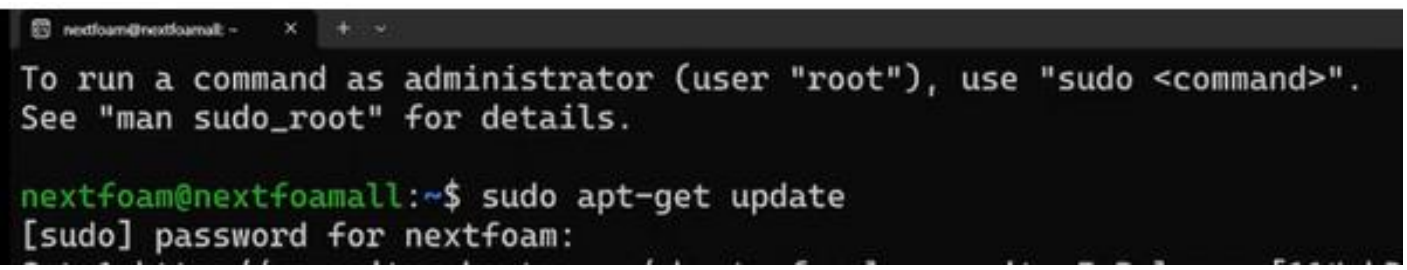
wsl -l -v



Ubuntu INSTALLが完了したため、
検索窓からUbuntuを選択し、Ubuntuを実行可能に！



Ubuntu 使用を円滑にするため、
最初は apt-get updateだけしておくと良い。

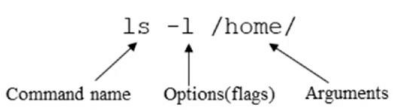


기본적인 리눅스 사용법 (1)

- 터미널 기본 short-cut key
  - ctrl + c : 명령 취소
  - ctrl + l : 터미널 클리어
  - ctrl + a : 커서를 처음으로 이동
  - ctrl + e : 커서를 끝으로 이동
  - ctrl + u : 커서 왼쪽 문자들 잘라내기
  - ctrl + k : 커서 오른쪽 문자들 잘라내기
  - ctrl + y : 버퍼에 저장되어 있는 내용 붙이기
  - ctrl + _ : 취소
  - alt + f : 커서 위치한 어절 끝으로 이동(커서 위치가 공백일 경우 다음 어절)
  - alt + b : 커서 위치한 어절 처음으로 이동(커서 위치가 공백일 경우 다음 어절)
  - alt + l : 문자열 끝까지 소문자로 변환
  - alt + u : 문자열 끝까지 대문자로 변환

기본적인 리눅스 사용법 (2)

- 리눅스 기본 명령어
  - 명령어 이름, 옵션(flag) 및 argument 를 터미널상 command line에 입력



  - 알아두면 좋은 명령어(1)
    - pwd: 현재 작업 디렉토리 표시
    - ls: 현재 작업 디렉토리에 위치한 파일 및 디렉토리 표시
    - touch: 비어있는 파일 생성
    - cp: 파일 혹은 디렉토리 복사
    - rm: 파일 및 디렉토리 삭제
    - mkdir: 디렉토리 생성
    - mv: 파일 및 디렉토리 이동 및 이름 변경
    - cd: 디렉토리 변경
    - tar: tar 형식의 압축파일 생성 및 해제

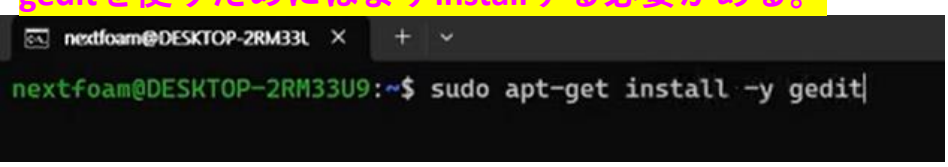
OpenFOAM 기본 강의 3강 (리눅스2-기본 명령어)

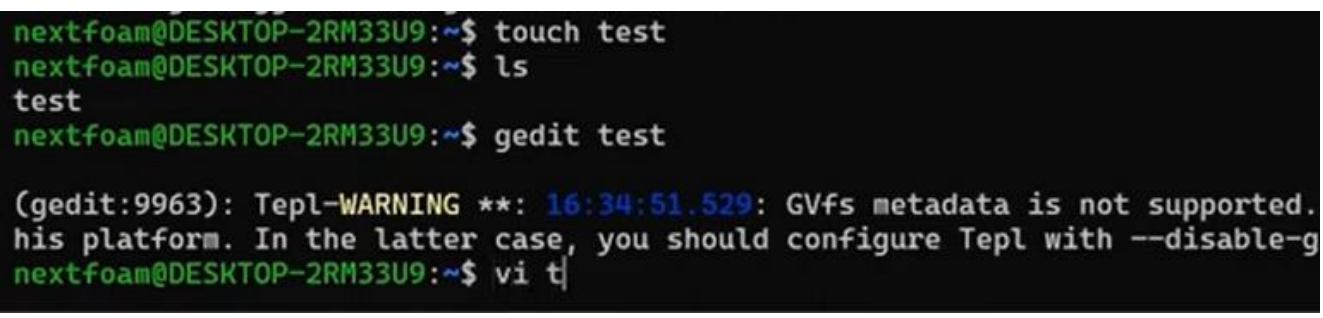
```
nextfoam@DESKTOP-2RM33U9:~$ pwd
/home/nextfoam
nextfoam@DESKTOP-2RM33U9:~$ ls
nextfoam@DESKTOP-2RM33U9:~$ touch file1
nextfoam@DESKTOP-2RM33U9:~$ ls
file1
nextfoam@DESKTOP-2RM33U9:~$ cp file1 file2
nextfoam@DESKTOP-2RM33U9:~$ ls
file1  file2
nextfoam@DESKTOP-2RM33U9:~$ rm file2
nextfoam@DESKTOP-2RM33U9:~$ ls
file1
nextfoam@DESKTOP-2RM33U9:~$ mkdir new
nextfoam@DESKTOP-2RM33U9:~$ ls
file1  new
nextfoam@DESKTOP-2RM33U9:~$ mv file1 file2
nextfoam@DESKTOP-2RM33U9:~$ ls
file2  new
nextfoam@DESKTOP-2RM33U9:~$ mv file2 new
nextfoam@DESKTOP-2RM33U9:~$ ls
new
nextfoam@DESKTOP-2RM33U9:~$ cd new
nextfoam@DESKTOP-2RM33U9:~/new$ ls
file2
nextfoam@DESKTOP-2RM33U9:~/new$ tar -cvf file2.tar file2
file2
nextfoam@DESKTOP-2RM33U9:~/new$ ls
file2  file2.tar
nextfoam@DESKTOP-2RM33U9:~/new$
```

기본적인 리눅스 사용법 (3)

- 리눅스 기본 명령어
  - 알아두면 좋은 명령어(2)
    - gedit : gedit을 이용하여 파일 열기
    - vi : vi(visual editor)를 이용하여 파일 열기
    - export : 환경변수 지정
    - source : 파일 및 기능들을 실행
    - man : 프로그램의 사용법을 보여줌
    - chmod : 폴더 및 파일의 권한을 변경
    - env : 현재 환경변수 목록을 출력
    - find : 파일 혹은 디렉토리 검색
    - sed : 필터링과 텍스트를 변환하는 스트림 편집기, 원본 변화 없이 출력 결과를 변화
    - grep : Global Regular Expression Print, 파일 상에서 정규표현식에 대응되는 모든 행 출력, 문자열(패턴) 검색에 사용
    - echo: 스트링 및 환경변수 출력
    - tree : 디렉토리의 하위 구조를 트리 형식으로 출력
  - 중요한 리눅스 명령어: I/O redirection
    - > : 실행결과를 파일로 출력
    - | : pipeline 명령어, 다수의 명령어를 연결하여 앞의 명령어 결과를 뒤의 명령어 입력으로 redirection

geditを使うためにはまずinstallする必要がある。

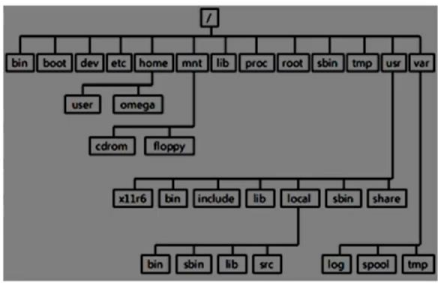




VIでもファイルを開いて修正することができる。
開いた後、INSERTキーで内容入力可能。。。
入力後にはESC キーを押してから、:x!で修正内容を保存できる。

리눅스 디렉토리 구조 (2)

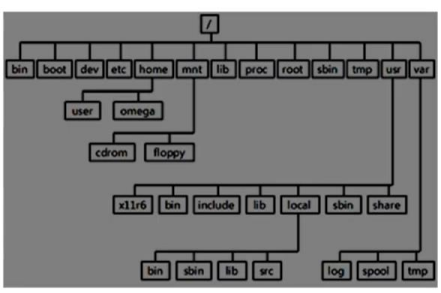
- 리눅스 기본 구조 설명
  - /
    - root를 의미
    - 마운트 되는 리눅스 파일 시스템이 있는 최상위 디렉토리
    - 시스템의 근간을 이루는 가장 중요한 디렉토리
    - 파티션 설정 시 반드시 존재하여야 함
    - 절대 경로의 기준이 되는 디렉토리
  - /bin
    - binarise의 약어
    - 리눅스의 기본 명령어(binary)들이 들어있는 디렉토리
    - 시스템을 운영하는데 기본적인 명령어들이 모여있는 디렉토리
    - 부팅에 필요한 명령어들이 위치하며 부팅 후 시스템의 사용자들이 사용할 수 있는 일반적인 명령어들도 위치하고 있음



절대경로: /(root) 디렉토리 기준
예) /usr/local
상대경로: 현재 작업 디렉토리 기준
예) ./local

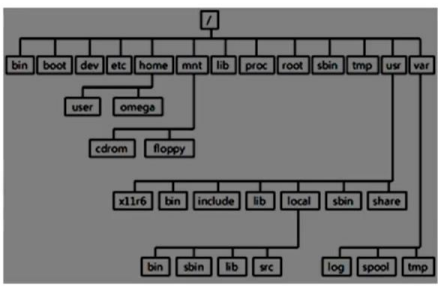
리눅스 디렉토리 구조 (3)

- 리눅스 기본 구조 설명
  - /sbin
    - 시스템 관리에 관련된 실행 명령어들이 들어있는 디렉토리
    - 시스템 점검 및 복구 명령, 시스템 초기 및 종료 명령 등 시스템 관리에 관련된 실행파일들이 존재
  - /lib
    - 프로그램들이 의존하고 있는 라이브러리 파일들을 포함
    - /lib/modules: 커널 모듈 파일들이 위치
    - 대부분의 라이브러리들은 링크 되어 있음
  - /etc
    - 시스템 환경 설정 파일이 위치하고 있음
    - 네트워크 관련 설정, 사용자 정보 및 암호 정보,파일 시스템 정보, 보안파일, 시스템 초기화 파일 등 중요 설정 파일들이 위치



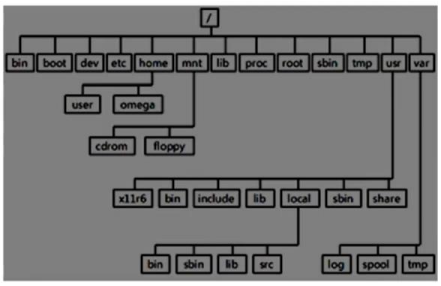
리눅스 디렉토리 구조 (4)

- 리눅스 기본 구조 설명
  - /proc
    - 시스템의 각종 프로세서, 프로그램 정보, 하드웨어적인 정보들이 저장
    - 가상 파일 시스템으로 /dev 디렉토리와 마찬가지로 하드 디스크상에 물리적 용량을 갖지 않음 (실제로 존재하지 않음)
      - 실제 하드 디스크에 저장되지 않고 커널에 의해서 메모리에 저장
    - 현재 시스템의 설정을 보여줌
    - 커널의 특정 기능을 제어할 수 있는 역할을 가지고 있음
      - 대부분 읽기 전용이나, 일부 파일 중에는 쓰기가 가능한 파일이 존재하는데 이러한 파일들에 특정 값을 지정하면 커널 기능이 변함
    - /proc 내의 파일을 cat 명령을 이용하여 보면 시스템 정보를 확인할 수 있음
      - 메모리 사용량의 정보 출력: cat /proc/meminfo



리눅스 디렉토리 구조 (5)

- 리눅스 기본 구조 설명
  - /var
    - 시스템에서 사용되는 동적 파일들이 저장
    - 시스템 운영 중에 시스템 자료 데이터가 변경될 때 변경된
    - 자료들이 저장되는 곳
    - 주로 시스템 작동 기록(log)들을 저장

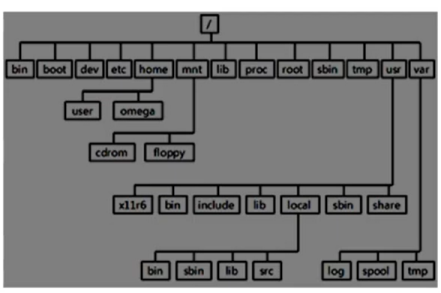


  - /home
    - 일반 사용자의 홈 디렉토리가 만들어지는 디렉토리
    - 사용자 계정을 만들면 계정과 같은 이름으로 새로운 사용자 디렉토리가 /home 디렉토리의 하위 디렉토리로 생성
      - /home/"username" : ~
      - 에) cd /home/nextfoam = cd ~

NEXTFOAM

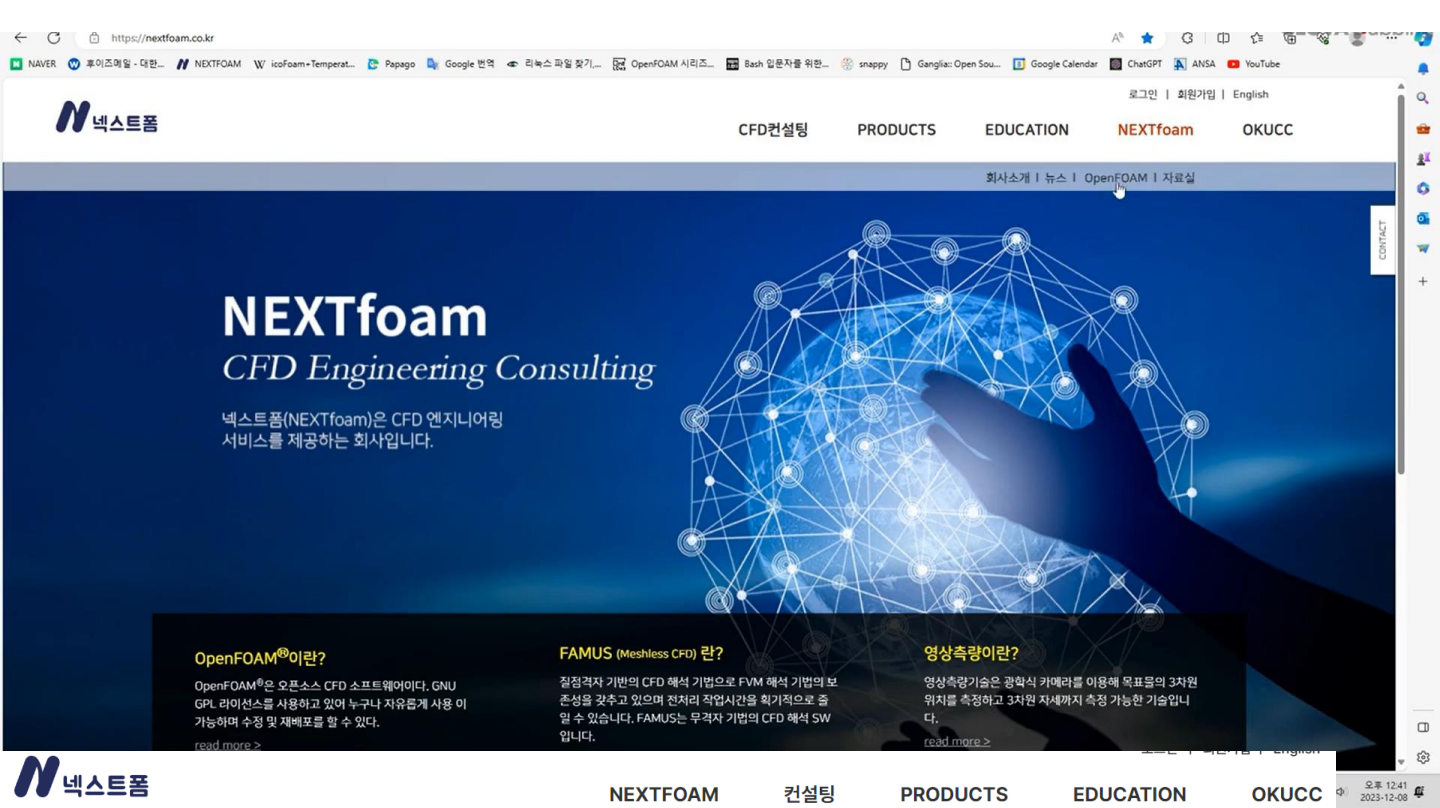
리눅스 디렉토리 구조 (6)

- 리눅스 기본 구조 설명
  - /boot
    - 부팅에 핵심적인 커널 이미지와 부팅 정보 파일을 담고 있음
    - /etc/lilo.conf에서 지정한 커널 부팅 이미지 파일이 들어 있으며 부팅 시 매우 중요한 디렉토리



  - /root
    - 슈퍼유저(root) 사용자의 홈 디렉토리
    - / 와 /root 디렉토리는 부르는 이름은 같음
  - /mnt
    - 다른 장치들을 마운트 할 때 일반적으로 사용되는 디렉토리

NEXTFOAM



넥스트폼 NEXTFOAM 컨설팅 PRODUCTS EDUCATION OKUCC

설치

OpenFOAM 이란? | 설치 | OpenFOAM 예제

OpenFOAM은 넥스트폼에서 제공하는 설치 파일을 이용해 손쉽게 설치가 가능하다. 아래 설치 파일을 이용하여 OpenFOAM을 설치하기 위해서는 CentOS 또는 Ubuntu 환경이 필요하다.

아래는 각 버전 별 OpenFOAM 설치파일이다.

- OpenFOAM6 (클릭)
- OpenFOAM9 (클릭)
- OpenFOAM v2112 (클릭)
- OpenFOAM v2212 (클릭)
- OpenFOAM v2312 (클릭)

openfoamをダウンロード

openfoam.com/download/release-history

23/12/2022: OpenFOAM v2212

Release Summary

Doxygen documentation

Platform	Download	MD sum
Source	OpenFOAM-v2212.tgz	889c9a2169c0b6911050de149a5b459
Source	ThirdParty-v2212.tgz	d60c9ebaaa25f4a061e034b7feed9d6
Windows MinGW	Installer.exe	

openfoam.com/download/release-history

25/06/2026: OpenFOAM v2406

Release Summary

Doxygen documentation

Platform	Download	MD sum
Source	OpenFOAM-v2406.tgz	0d01e49d7973978cd3dcaf766f1b782a
Source	ThirdParty-v2406.tgz	4d0e3df3adc2a8d50aaab6e1b8b67892
Windows MinGW	Installer.exe	TBA

3 件のサイト を検索しました

The current version of CFD-OF (CFD for OpenFOAM) is compatible with OpenFOAM version 5.x. This is a relatively older version of OpenFOAM, and it seems that there are some challenges and compatibility issues with newer versions like OpenFOAM 7 or 8. The difficulty lies in migrating and maintaining compatibility with newer OpenFOAM versions due to frequent changes in library names, include paths, and model behaviors(CFDEM).

If you are looking for a setup that works with newer OpenFOAM versions, you might want to explore different CFD-OF configurations or look for community discussions that may have tried newer versions with some success. There are also forks of OpenFOAM that aim to be compatible with more recent versions, but these require specific setups(SimFlow).

For more details, you can visit the official CFD-OF or OpenFOAM community forums where users and developers discuss compatibility issues and possible solutions.

Reason for Different Naming Conventions:

The OpenFOAM Foundation and ESI-OpenCFD, which are different entities managing different releases, have adopted separate versioning conventions:

- The **OpenFOAM Foundation** typically releases versions following the numerical format (e.g., OpenFOAM 9).
- **ESI-OpenCFD** uses the date-based format (e.g., OpenFOAM v2212), aligning the version name with the release date for easier reference to when a version was released.

openfoam.org/download/history/

Release History

Announcements of OpenFOAM Releases since version 1.0 in 2004

OpenFOAM 12 Released
9th July 2024
Read More

OpenFOAM 11 Released
11th July 2023
Read More

OpenFOAM 10 Released
12th July 2022
Read More

OpenFOAM 9 Released
20th July 2021
Read More

OpenFOAM 8 Released
22nd July 2020
Read More

OpenFOAM 7 Released
8th July 2019
Read More

OpenFOAM 6 Released
10th July 2018
Read More

OpenFOAM 5.0 Released
26th July 2017
Read More

OpenFOAM 4.1 Released
13th October 2016
Read More

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25/06/2026: OpenFOAM v2406

Release Summary

Doxygen documentation

Platform	Download	MD sum
Source	OpenFOAM-v2406.tgz	0d01e49d7973978cd3dcaf766f1b782a
Source	ThirdParty-v2406.tgz	4d0e3df3adc2a8d50aaab6e1b8b67892
Windows MinGW	Installer.exe	TBA

23/12/2022: OpenFOAM v2212

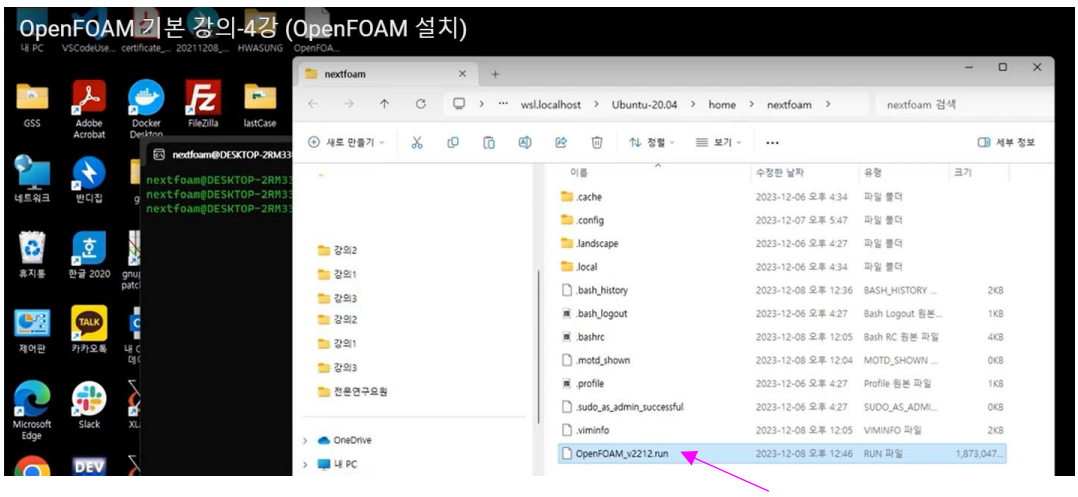
Release Summary

Doxygen documentation

Platform	Download	MD sum
Source	OpenFOAM-v2212.tgz	889c9a2169c0b6911050de149a5b459b
Source	ThirdParty-v2212.tgz	d60c9ebaaa25f4a061e034b7feed9d6b
Windows MinGW	Installer.exe	

Ubuntuでhome directoryに移動した後に、explorerを開いて
そこにdownloadしておいたopenfoamのinstallerをcopyしておく。

```
nextfoam@DESKTOP-2RM33U9:~$ cd
nextfoam@DESKTOP-2RM33U9:~$ explorer
```




```
nextfoam@DESKTOP-2RM33U9:~$ cd
nextfoam@DESKTOP-2RM33U9:~$ explorer.exe .
nextfoam@DESKTOP-2RM33U9:~$ ls
OpenFOAM_v2212.run  OpenFOAM_v2212.run:Zone.Identifier
nextfoam@DESKTOP-2RM33U9:~$ chmod +x OpenFOAM_v2212.run
nextfoam@DESKTOP-2RM33U9:~$ ls
OpenFOAM_v2212.run  OpenFOAM_v2212.run:Zone.Identifier
nextfoam@DESKTOP-2RM33U9:~$ ./OpenFOAM_v2212.run
Verifying archive integrity... All good.
Uncompressing OpenFOAM-v2212 Installer...    42%
```

実行可能な
ファイル形式
に変更すると、
緑色に代わって
Install可能になる

```
nextfoam@DESKTOP-2RM33U9:~$ cd
nextfoam@DESKTOP-2RM33U9:~$ explorer.exe .
nextfoam@DESKTOP-2RM33U9:~$ ls
OpenFOAM_v2212.run  OpenFOAM_v2212.run:Zone.Identifier
nextfoam@DESKTOP-2RM33U9:~$ chmod +x OpenFOAM_v2212.run
nextfoam@DESKTOP-2RM33U9:~$ ls
OpenFOAM_v2212.run  OpenFOAM_v2212.run:Zone.Identifier
nextfoam@DESKTOP-2RM33U9:~$ ./OpenFOAM_v2212.run
Verifying archive integrity... All good.
Uncompressing OpenFOAM-v2212 Installer...  100%
Specify your installation directory :  ~/apps
The directory '/home/nextfoam/apps' does not exist. Do you want to create the directory? [y/n] :  y

Installing OpenFOAM-v2212
 491MiB 0:00:11 [42.2MiB/s] [==========================================================================

Do you want to install Development Tools? [y/n] :  y
Installing Development Tools
 444MiB 0:00:07 [61.2MiB/s] [==========================================================================

Do you want to install ThirdParty? [y/n] :  y
Do you want to install ParaView with osmesa? [y/n] :  n
Installing ParaView-5.9.1 without osmesa
 132MiB 0:00:02 [50.9MiB/s] [==========================================================================
Installing mesa-21.3.7
85.6MiB 0:00:01 [54.9MiB/s] [==========================================================================
Installing qt-5.15.2
```

OpenFOAM 기본 강의-4강 (OpenFOAM 설치)

```
Installing metis-5.1.0
85.8kiB 0:00:00 [ 169MiB/s] [=====
Installing gnuplot-5.4.3
1016kiB 0:00:00 [63.1MiB/s] [=====

There is no InfiniBand device in
Configuring ThirdParty...
Done.

Installation complete.
Set your environment variables to load :
        '/home/nextfoam/apps/OpenFOAM-v2212/etc/bashrc'

nextfoam@DESKTOP-2RM33U9:~$ gedit ~/.bashrc

** (gedit:37195): WARNING **: 12:50:52.086: Could not load the
```

.bashrc

```
111 if ! shopt -oq posix; then
112   if [ -f /usr/share/bash-completion/bash_completion ]; then
113     . /usr/share/bash-completion/bash_completion
114   elif [ -f /etc/bash_completion ]; then
115     . /etc/bash_completion
116   fi
117 fi
```

sh ▾ Tab Width: 8 ▾ Ln 1, Col 1 ▾ INS

設置最後に環境変数の設定が必要とのメッセージがあるので、
Gedit ~/.bashrcを開いて
最後の行に/home/nextfoam/apps/OpenFOAM…
を追加後にSAVE

Open ▾ Save

```
111 if ! shopt -oq posix; then
112   if [ -f /usr/share/bash-completion/bash_completion ]; then
113     . /usr/share/bash-completion/bash_completion
114   elif [ -f /etc/bash_completion ]; then
115     . /etc/bash_completion
116   fi
117 fi
118
119 source /home/nextfoam/apps/OpenFOAM-v2212/etc/bashrc
```

Saving file "/home/nextfoam/.bashrc"… sh ▾ Tab Width: 8 ▾ Ln 119, Col 53 ▾ INS

```
Installation complete.
Set your environment variables to load :
        '/home/nextfoam/apps/OpenFOAM-v2212/etc/bashrc'

nextfoam@DESKTOP-2RM33U9:~$ gedit ~/.bashrc

** (gedit:37195): WARNING **: 12:50:52.086: Could not load theme icon text-x-gen

(gedit:37195): Tepl-WARNING **: 12:51:23.233: GVfs metadata is not supported. Fa
 latter case, you should configure Tepl with --disable-gvfs-metadata.
nextfoam@DESKTOP-2RM33U9:~$ source ~/.bashrc
nextfoam@DESKTOP-2RM33U9:~$ simpleFoam
```

Sourceで変更内容をすぐにも適用させる。

simpleFoamで計算ができるかを確認。
ここでは、まだopenfoamの入力ファイルを
用意していないので、エラーでているが、
Openfoamは問題なく立ち上がるもとが分かる。

```
Installation complete.
Set your environment variables to load :
        '/home/nextfoam/apps/OpenFOAM-v2212/etc/bashrc'

nextfoam@DESKTOP-2RM33U9:~$ gedit ~/.bashrc

** (gedit:37195): WARNING **: 12:50:52.086: Could not load theme icon text-x-generic: Icon 'text-x-generic' not present in theme Adwaita

(gedit:37195): Tepl-WARNING **: 12:51:23.233: GVfs metadata is not supported. Fallback to TeplMetadataManager. Either GVfs is not correct
 latter case, you should configure Tepl with --disable-gvfs-metadata.
nextfoam@DESKTOP-2RM33U9:~$ source ~/.bashrc
nextfoam@DESKTOP-2RM33U9:~$ simpleFoam
/*---------------------------------------------------------------------------*\
| =========                 |                                                 |
| \\      /  F ield         | OpenFOAM: The Open Source CFD Toolbox           |
|  \\    /   O peration     | Version:  2212                                  |
|   \\  /    A nd           | Website:  www.openfoam.com                      |
|    \\/     M anipulation  |                                                 |
\*---------------------------------------------------------------------------*/
Build  : v2212 OPENFOAM=2212 version=v2212
Arch   : "LSB;label=32;scalar=64"
Exec   : simpleFoam
Date   : Dec 08 2023
Time   : 12:51:52
Host   : DESKTOP-2RM33U9
PID    : 37742
I/O    : uncollated
Case   : /home/nextfoam
nProcs : 1
trapFpe: Floating point exception trapping enabled (FOAM_SIGFPE).
fileModificationChecking : Monitoring run-time modified files using timeStampMaster (fileModificationSkew 5, maxFileModificationPolls 20)
allowSystemOperations : Allowing user-supplied system call operations

// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * //
Create time



--> FOAM FATAL ERROR: (openfoam-2212)
cannot find file "/home/nextfoam/system/controlDict"

    From virtual Foam::autoPtr<Foam::ISstream> Foam::fileOperations::uncollatedFileOperation::readStream(Foam::regIOobject&, const Foam::
    in file global/fileOperations/uncollatedFileOperation/uncollatedFileOperation.C at line 561.

FOAM exiting

nextfoam@DESKTOP-2RM33U9:~$
```

再生 (k) 3:37 / 4:01

총 23 건의 게시글이 있습니다.

번호	제목	등록일
3	Baram-v1.0-예제1	18-10-15
2	오픈폼GUI_Baram-v1.0	18-10-15
1	오픈폼(OpenFOAM) 한글 매뉴얼	18-10-15

2014년에 KISTI와 넥스트폼이 제작한 "공개 전산열유체 시뮬레이션 OpenFOAM의 설치 및 사용 매뉴얼" 입니다.

공개_전산열유체_시뮬레이션_OpenFOAM.pdf

환경변수(Environment variables)

- 환경변수란?
  - 프로세스가 컴퓨터에서 동작하는 방식에 영향을 미치는, 동적 값들의 모임
  - 로컬 환경변수, 사용자 환경변수 그리고 시스템 환경변수가 존재
    - 로컬 환경변수(Local environment variables): 현재 진행중인 세션에만 동작하는 환경변수
    - 사용자 환경 변수 (User environment variables): 특정 사용자에 대해서만 정의된 환경 변수로 로컬 터미널 세션, 원격 로그인 세션을 사용하여 로그인할 때 로드 됨
      - ~/.bashrc , ~/.profile
    - 시스템 환경 변수 (System environment variables): 해당 시스템에 존재하는 모든 사용자가 사용할 수 있는 환경변수
      - /etc/bashrc, /etc/profile

```
nextfoam@DESKTOP-2RM33U9:/etc$ sudo gedit profile
[sudo] password for nextfoam:
```

Open *profile /etc

```
1 # /etc/profile: system-wide .profile file for the Bourne
2 # and Bourne compatible shells (bash(1), ksh(1), ash(1),
3
4 if [ "${PS1-}" ]; then
5   if [ "${BASH-}" ] && [ "$BASH" != "/bin/sh" ]; then
6     # The file bash.bashrc already sets the default PS1.
7     # PS1='\h:\w\$ '
8     if [ -f /etc/bash.bashrc ]; then
9       . /etc/bash.bashrc
10    fi
11  else
12    if [ "`id -u`" -eq 0 ]; then
13      PS1='# '
14    else
15      PS1='$ '
16    fi
17  fi
18 fi
19
20 if [ -d /etc/profile.d ]; then
21   for i in /etc/profile.d/*.sh; do
22     if [ -r $i ]; then
23       . $i
24     fi
25   done
26   unset i
27 fi
28
29 export DOKDO="Korea"
```

```
foamfoam@DESKTOP-2RM33
nextfoam@DESKTOP-2RM33U9:~$ sudo adduser foamfoam
[sudo] password for nextfoam:
Adding user `foamfoam' ...
Adding new group `foamfoam' (1002) ...
Adding new user `foamfoam' (1002) with group `foamfoam' ...
Creating home directory `/home/foamfoam' ...
Copying files from `/etc/skel' ...
New password:
Retype new password:
passwd: password updated successfully
Changing the user information for foamfoam
Enter the new value, or press ENTER for the default
        Full Name []:
        Room Number []:
        Work Phone []:
        Home Phone []:
        Other []:
Is the information correct? [Y/n] Y
nextfoam@DESKTOP-2RM33U9:~$ echo $DOKDO
Korea
nextfoam@DESKTOP-2RM33U9:~$ su foamfoam
Password:
foamfoam@DESKTOP-2RM33U9:/home/nextfoam$ echo $DOKDO
Korea
foamfoam@DESKTOP-2RM33U9:/home/nextfoam$
```

OpenFOAM 환경변수

- OpenFOAM 환경변수
  - 오픈폼이 설치된 디렉토리의 /etc/bashrc 에서 정의
  - Source시, 기본적으로 설정되는 디렉토리 관련 환경변수 예시

```
$WM_PROJECT_DIR: OpenFOAM 소스코드 디렉토리
$WM_THIRD_PARTY_DIR: Third-party 위치 디렉토리
$FOAM_APP: $WM_PROJECT_DIR/applications
$FOAM_SOLVERS: $WM_PROJECT_DIR/applications/solvers
$FOAM_UTILITIES: $WM_PROJECT_DIR/applications/utilities
$FOAM_SRC: $WM_PROJECT_DIR/src
$FOAM_ETC: $WM_PROJECT_DIR/etc
$FOAM_TUTORIALS: $WM_PROJECT_DIR/Tutorials
$FOAM_APPBIN: $WM_PROJECT_DIR/platforms/"linuxXXGCCDPIntXXOpt"/bin
$FOAM_LIBBIN: $WM_PROJECT_DIR/platforms/"linuxXXGCCDPIntXXOpt"/lib
```

OpenFOAM 환경변수

- OpenFOAM 사용자 환경변수
  - OpenFOAM 설치시 기본적으로 설정되어있는 디렉토리 관련 사용 환경변수
    - 사용자 작업공간을 따로 분리하여 사용하도록 설정 되어있음 (사용하지 않아도 무관)
  - `$WM_PROJECT_USER_DIR: OpenFOAM USER` 디렉토리

    `$FOAM_RUN: $WM_PROJECT_USER_DIR/run`

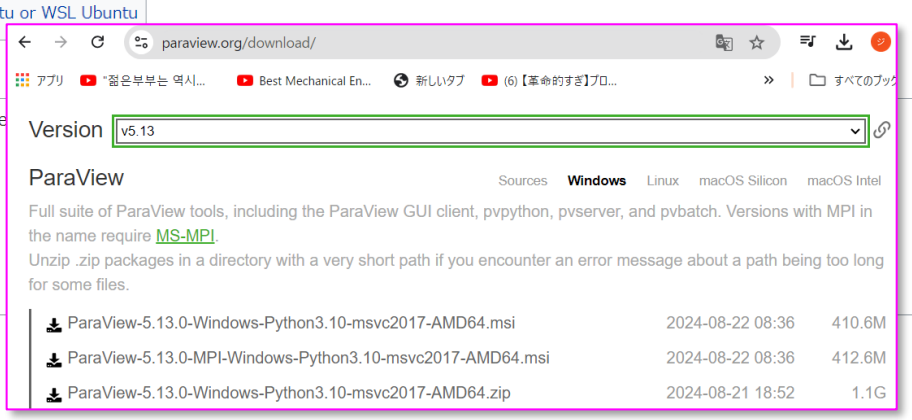
    `$FOAM_USER_APPBIN: $WM_PROJECT_USER_DIR/platforms/"linuxXXGCCDPIntXXOpt"/bin`

    `$FOAM_USER_LIBBIN: $WM_PROJECT_USER_DIR/platforms/"linuxXXGCCDPIntXXOpt"/lib`
  - APPBIN vs LIBBIN
    - Solver 혹은 utility를 compile 할 경우 `$FOAM_APPBIN` 에 실행파일(*.so) 저장
    - Library를 compile 할 경우 `$FOAM_LIBBIN`에 실행파일(*.so) 저장
    - USER의 경우 사용자 개발 solver 혹은 library 실행파일 (*.so)들이 저장
      - 사용자 개발 프로그램과 기존 OpenFOAM과 구분되어 분리하는 것이 좋음

다른 사이트에서는 조금더 **간단히 ?**.

Wsl1환경 구축후,
Ubuntu설치,
Openfoam설치하는 예도 있다…

https://wiki.cusf.co.uk/OpenFOAM_installation_instructions#Windows_10_and_above:_Install_WSL_Ubuntu



INSTALL PARAVIEW

Install and Use ParaView

If you wish to view the results of the simulations, the

Windows 10 and above:

Simply download the executable for Windows 10 from this website.

The same website also hosts excellent tutorials and documentation PDFs - these should be your first resource when learning how to use ParaView.

In order to run ParaView from the command line, you must add `paraview.exe` to Path:

- Find the folder containing your `paraview.exe` executable, and copy the folder's location (not the file's location) to your clipboard with `CTRL+C`.
- In the search bar, type "Edit the system environment variables" and click the first option.
- Click the box labelled "Environment Variables..." in the lower right corner.
- A dialogue box appears. In the lower half labelled "System Variables", scroll to the variable "Path"
- Double click on the "Path" variable.
- Click "New"
- Paste the folder path you copied earlier into the text box that is now selected.
- Click "OK" on all the dialogue boxes.

You can now open files in ParaView from the command line with `paraview.exe <file>`, replacing `<file>` with the file you wish to open.

Ubuntu:

Simply run this command:

```
sudo apt-get install paraview
```

You can now open files in ParaView from the command line with `paraview <file>`, replacing `<file>` with the file you wish to open.

INSTALL WSL FOR LINUX USE IN WINDOWS

Windows 10 and above: Install WSL Ubuntu

Install Windows Subsystem for Linux version 1 (WSL1, not WSL2).

If you have never used a command line on Linux (or related systems), then the first 10 minutes of this video might be helpful. The whole video is great, but the first 10 minutes are the absolute essentials.

WSL Version comparison (optional):

- *WSL1 Pros: fairly fast read/write in both Ubuntu and Windows file systems. Cons: much slower at read/write in Ubuntu file system than WSL2.*
- *WSL2 Pros: lightning fast read/write in Ubuntu. Cons: very slow read/write when moving data between Ubuntu and Windows.*
- *Summary: Use WSL1 if you have a Windows-based ParaView or another app that will read lots of data between file systems.*
  - *If you want to use WSL2 anyway, I recommend you install ParaView on Ubuntu to avoid reading between file systems. You must also install XMing to view the GUI. See this page and this page for further information.*

INSTALL WSL FOR LINUX USE IN WINDOWS
and then, Linux (ex, Ubuntu)

1,006 回視聴 2023/12/12 #강의영상 #openfoam #cfd
#오픈폼 #openfoam #cfd #넥스트폼 #강의영상

wsl 설치 명령어

if you wish to only install WSL 1, you can now **restart** your machine and move on to Step 3 - Install your Linux distribution of choice. To update to WSL 2, **wait to restart** your machine and move on to the next step.

1. dism.exe /online /enable-feature /featurename:Microsoft-Windows-Subsystem-Linux /all /norestart
   WSL1は、これだけで次は、3
2. dism.exe /online /enable-feature /featurename:VirtualMachinePlatform /all /norestart
   WSL2設置のための、virtualmachine?

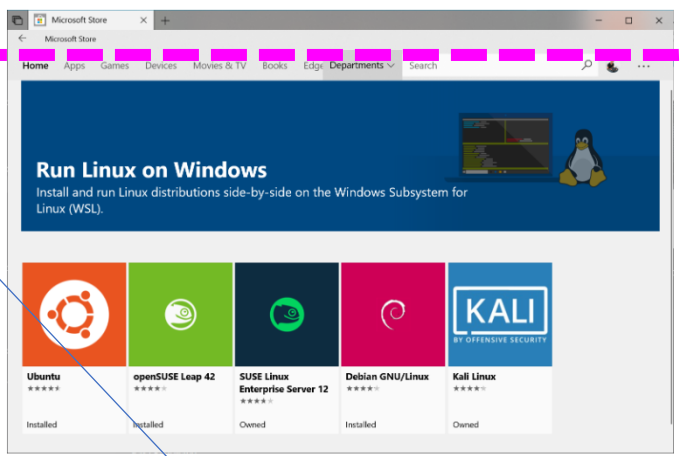
3. wsl --install -d Ubuntu-20.04

4. wsl -l -v

*wsl 1일 경우*後でも、以下でupgate可能
wsl --update
wsl --shutdown
wsl -l -v
wsl --set-version Ubuntu-20.04 2

Step 6 - Install your Linux distribution of choice

1. Open the Microsoft Store and select your favorite Linux distribution.



The following links will open the Microsoft store page for each distribution:

- Ubuntu 18.04 LTS
- Ubuntu 20.04 LTS

最新バージョン？

INSTALL OPENFOAM

Install OpenFOAM on Native Ubuntu or WSL Ubuntu

OpenFOAM is an open-source Computational Fluid Dynamics (CFD) package. We will use it to simulate the fluid (air) flow.

The Ubuntu (Native or WSL) installation instructions as of 31/12/2021 are summarised below (adapted from this website)

First, update the package index and upgrade the packages.

```
sudo apt update
sudo apt upgrade
```

If the first command fails with an error message that looks like `Certificate validation failed: The certificate is NOT trusted ... N: Updating from such a repository can't be done securely...` then run `sudo apt upgrade` anyway, and re-run `sudo apt update`, followed by `sudo apt upgrade`

```
curl -s https://dl.openfoam.com/add-debian-repo.sh | sudo bash
sudo apt-get install openfoam2112-default
```

Append the following line to your `~/.bashrc` file, if not already present. If you don't know how to do this, run `nano ~/.bashrc`, navigate to the bottom of the file with the arrow keys, and type the line in.

```
source /usr/lib/openfoam/openfoam2112/etc/bashrc
```

Remember that `^X` which is `CTRL+X` exits nano. `^` is short for the `CTRL` button. Make sure to type `Y` on the prompt `Save modified buffer?` after pressing `CTRL+X`

Restart Ubuntu. Now check the installation completed correctly by running a tutorial case:

```
cd ~
mkdir -p OpenFOAM-sims/tutorials
cp -r $FOAM_TUTORIALS/incompressible OpenFOAM-sims/tutorials
cd OpenFOAM-sims/tutorials/incompressible/icoFoam/cavity/cavity/
blockMesh > log.blockMesh
icoFoam > log.icoFoam
touch foam.foam
```

You can now view the results in ParaView:

- WSL Ubuntu: `paraview.exe foam.foam`
- Native Ubuntu: `paraview foam.foam`

OpenFOAM 솔버 소개

Solvers in OpenFOAM

- In **$FOAM_SOLVERS** you find the source code for the solvers arranged according to:

basic	discreteMethods	financial	lagrangian
combution	DNS	heatTransfer	multiphase
compressible	electromagnetics	incompressible	stressAnalysis

  - We will have a look at the incompressible solvers.
- In **$FOAM_SOLVERS/incompressible** you find the solver source code directories:

adjointShapeOptimizationFoam	icoFoam	pimpleFoam	shallowWaterFoam
boundaryFoam	nonNewtonianIcoFoam	pisoFoam	simpleFoam

- Inside each solver directory you find a `*.C` file with the same name as the directory. This is the main file, where you will find the top-level source code and a short description of the solver. For `icoFoam` :
  - Transient solver for incompressible, laminar flow of Newtonian fluids.

Standard Solvers

- Basic solvers

Solver	Description
laplacianFoam	Solves a simple Laplace equation, e.g. for thermal diffusion in a solid.
potentialFoam	Potential flow solver which solves for the velocity potential, to calculate the flux-field, from which the velocity field is obtained by reconstructing the flux.
scalarTransportFoam	Solves the steady or transient transport equation for a passive scalar.

Standard Solvers

- Incompressible flow solvers

Solver	Description
adjointShapeOptimizationFoam	Steady-state solver for incompressible, turbulent flow of non-Newtonian fluids with optimization of duct shape by applying “blockage” in regions causing pressure loss as estimated using an adjoint formulation.
boundaryFoam	Steady-state solver for incompressible, 1D turbulent flow, typically to generate boundary layer conditions at an inlet, for use in a simulation.
icoFoam	Transient solver for incompressible, laminar flow of Newtonian fluids.
nonNewtonianIcoFoam	Transient solver for incompressible, laminar flow of non-Newtonian fluids.
pimpleFoam	Transient solver for incompressible, turbulent flow of Newtonian fluids, with optional mesh motion and mesh topology changes.

Standard Solvers

Solver	Description
SRFPimpleFoam	Large time-step transient solver for incompressible, turbulent flow in a single rotating frame.
pisoFoam	Transient solver for incompressible, turbulent flow, using the PISO algorithm.
shallowWaterFoam	Transient solver for inviscid shallow-water equations with rotation.
simpleFoam	Steady-state solver for incompressible, turbulent flow, using the SIMPLE algo rithm.
porousSimpleFoam	Steady-state solver for incompressible, turbulent flow with implicit or explicit porosity treatment and support for multiple reference frames(MRF)
SRFSimpleFoam	Steady-state solver for incompressible, turbulent flow of non-Newtonian flui ds in a single rotating frame.

Standard Solvers

- Compressible flow solvers

Solver	Description
rhoCentralFoam	Density-based compressible flow solver based on central-upwind schemes of Kurganov and Tadmor.
rhoPorousSimpleFoam	Steady-state solver for turbulent flow of compressible fluids, with implicit o r explicit porosity treatment and optional sources.
rhoPimpleFoam	Transient solver for turbulent flow of compressible fluids for HAVC and simi lar applications, with optional mesh motion and mesh topology changes.
rhoSimpleFoam	Steady-state solver for turbulent flow of compressible fluids.

Standard Solvers

- Multiphase flow solvers

Solver	Description
cavitatingFoam	Transient cavitation code based on the homogeneous equilibrium model from which the compressibility of the liquid / vapour “mixture” is obtained.
compressibleInterFoam	Solver for 2 compressible, non-isothermal immiscible fluids using a VOF(volume of fluid) phase-fraction based interface capturing approach.
compressibleMultiphaseInterFoam	Solver for n compressible, non-isothermal immiscible fluids using a VOF phase-fraction based interface capturing approach.
driftFluxFoam	Solver for 2 incompressible fluids using the mixture approach with the drift-flux approximation for relative motion of the phases.

Standard Solvers

Solver	Description
potentialFreeSurfaceFoam	Incompressible Navier-Stokes solver with inclusion of a wave height field to enable single-phase free-surface approximations, with optional mesh motion and mesh topology changes.
twoLiquidMixingFoam	Solver for mixing 2 incompressible fluids.

Standard Solvers

- Direct numerical simulation (DNS)

Solver	Description
dnsFoam	Direct numerical simulation solver for boxes of isotropic turbulence.

- Combustion solvers

Solver	Description
chemFoam	Solver for chemistry problems, designed for use on single cell cases to provide comparison against other chemistry solvers, that uses a single cell mesh, and fields created from the initial conditions.
coldEngineFoam	Solver for cold-flow in internal combustion engines.
engineFoam	Solver for internal combustion engines.
PDRFoam	Solver for compressible premixed / partially-premixed combustion with turbulence modeling.

Standard Solvers

- Heat transfer and buoyancy-driven flows solvers

Solver	Description
buoyantPimpleFoam	Transient solver for buoyant, turbulent flow of compressible fluids for ventilation and heat-transfer.
bouyantSimpleFoam	Steady-state solver for buoyant, turbulent flow of compressible fluids, including radiation, for ventilation and heat-transfer.
chtMultiRegionFoam	Solver for steady or transient fluid flow and solid heat conduction, with conjugate heat transfer between regions, buoyancy effects, turbulence, reactions and radiation modelling.
thermoFoam	Solver for energy transport and thermodynamics on a frozen flow field.

Standard Solvers

- Particle-tracking flows solvers

Solver	Description
denseParticleFoam	Transient solver for the coupled transport of particle clouds including the effect of the volume fraction of particles on the continuous phase, with optional mesh motion and mesh topology changes.
particleFoam	Transient solver for the passive transport of a single kinematic particle cloud, with optional mesh motion and mesh topology changes.
rhoParticleFoam	Transient solver for the passive transport of a particle cloud.

Standard Solvers

- Discrete methods solvers

Solver	Description
dsmcFoam	Direct simulation Monte Carlo (DSMC) solver for, transient, multi-species flo ws.
mdEquilibrationFoam	Solver to equilibrate and / or precondition molecular dynamics systems.
mdFoam	Molecular dynamics solver for fluid dynamics.

- Electromagnetics solvers

Solver	Description
electrostaticFoam	Solver for electrostatics.
magneticFoam	Solver for the magnetic field generated by permanent magnets.
mhdFoam	Solver for magnetohydrodynamics(MHD) : incompressible, laminar flow of a conducting fluid under the influence of a magnetic field.

Standard Solvers

- Stress analysis of solids solvers

Solver	Description
solidDisplacementFoam	Transient segregated finite-volume solver of linear-elastic, small-strain deformation of a solid body, with optional thermal diffusion and thermal stresses.
solidEquilibriumDisplacementFoam	Steady-state segregated finite-volume solver of linear-elastic, small-strain deformation of a solid body, with optional thermal diffusion and thermal stre sses.

- Finance solvers

Solver	Description
financialFoam	Solves the Black-Scholes equation to price commondities.

OpenFOAM 폴더구조

OpenFOAM 디렉토리 구조(applications)

- 아래와 같은 명령어로 applications 디렉토리 하위 구조를 확인할 수 있음

```
$ tree -L 1 -d $WM_PROJECT_DIR/applications
OpenFOAM-v2212/applications
├── solvers
├── test
├── tools
└── utilities
```

- Applications 에는 OpenFOAM 에서 제공하는 솔버 및 유틸리티의 소스코드들이 위치
  - solvers: 현재 OpenFOAM 버전에서 배포된 솔버들의 소스코드 모음
  - test: OpenFOAM에서 사용되는 클래스 및 라이브러리 테스트를 위한 짧은 소스코드 모음
  - utilities: OpenFOAM에서 사용되는 유틸리티들의 소스코드 모음
  - 격자 변환, 병렬 계산, 전처리 및 case 셋팅 등

OpenFOAM 디렉터리 구조(src)

- OpenFOAM 라이브러리들이 정리되어 있음
  - 하나의 폴더가 하나의 라이브러리
    - **finiteVolume :**
      - 유한체적법의 수치해석 기법 관련된 소스코드들을 포함하고 있음
      - 예) numerical scheme, boundary condition, finite volume mesh 등
    - **OpenFOAM :**
      - OpenFOAM 에서 사용하는 변수, operation 및 격자 정보 관련 클래스들을 포함하고 있음
      - 예) label, vector, List, Field, GeometricField, primitiveMesh, polyMesh 등
    - **parallel :** 병렬 알고리즘 관련 라이브러리
      applications/utilites 에 있는 parallel 과 별개
    - **TurbulenceModels :** 난류모델 라이브러리
    - **thermophysicalModels :** 열물리 관련 라이브러리
    - **dynamicMesh :** 동적격자 라이브러리

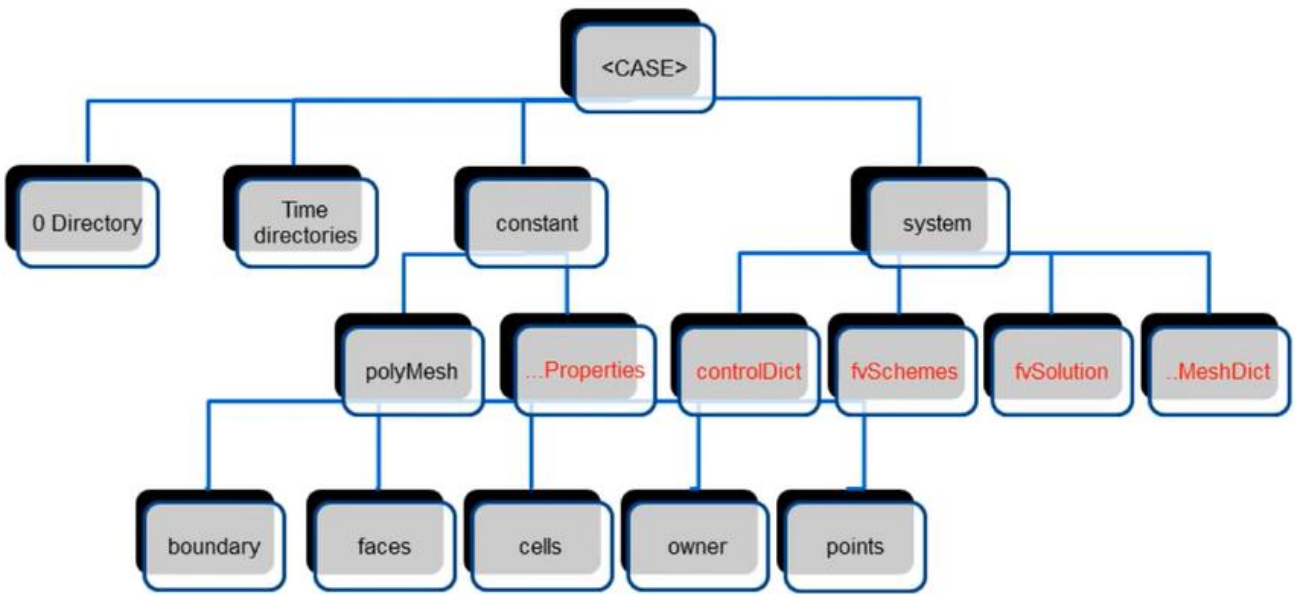
OpenFOAM 디렉토리 구조(bin,doc,lib,Tutorials)

- **bin** 디렉토리는 쉘스크립트를 포함하고 있음(paraFoam, foamNew, foamLog)
  - **ParaFoam:** OpenFOAM 라이브러리로 paraView 실행
  - **FoamNew:** 새로운 클래스의 기본 틀 생성
  - **FoamLog:** OpenFOAM 로그 상에서 데이터를 추출
- **doc** 디렉토리는 OpenFOAM 관련된 문서를 포함하고 있음
  - pdf 형식의 **UserGuide**
    `$ evince $WM_PROJECT_DIR/doc/Guides/OpenFOAMUserGuide-A4.pdf`
  - Html 형식의 **Doxygen documentation**
- **etc** 디렉토리에는 OpenFOAM 환경변수 설정 파일 및 OpenFOAM dictionary 사용법 및 default thermoData를 포함하고 있음
- **Tutorials** 디렉토리에는 OpenFOAM 솔버에 해당하는 예제를 포함하고 있음
  - 모든 솔버에 대한 예제를 포함하고 있지는 않음

OpenFOAM 디렉토리 구조(wmake)

- OpenFOAM에서는 소스코드 컴파일을 위해 **wmake**라는 명령어를 사용
- **wmake**는 OpenFOAM의 파일 구조를 읽어들인 후 **wmake** 디렉토리에서 정의되어 있는 기본 컴파일러를 이용하여 컴파일함
- **wmake** 결과를 초기화 해주는 **wclean** 명령어도 있음
- 컴파일러 이름은 **$WM_PROJECT_DIR/etc/bashrc** 에서 정의됨
  - 이에 해당하는 **wmake** interpreter를 **wmake/rules** 디렉토리에 정의해 주어야 함
  - OpenFOAM 컴파일 및 clean up 관련 자료들은 OpenFOAM wiki 등 에서 찾아볼 수 있음

File Structure of OpenFOAM Cases



0 Directory

- The 0 directory contains the dimensions, and the initial and boundary conditions for all primary variables, such as p and U.

```
dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0 0 0);

boundaryField
{
    inlet
    {
        type            fixedValue;
        value           uniform (10 0 0);
    }

    outlet
    {
        type            zeroGradient;
    }

    upperWall
    {
        type            noSlip;
    }

    lowerWall
    {
        type            noSlip;
    }

    frontAndBack
    {
        type            empty;
    }
}
```

U file example

0 Directory files

0 Directory

[kg m s K mol A Cd]

- *dimensions* `[0 1 -1 0 0 0 0];` states that the dimension of `U` is *m/s*.
- `internalField uniform (0 0 0);` sets `U` to zero internally.
- The boundary patches `inlet` and `upperWall` are given the *type* `fixedValue and noSlip respectively; inlet` value is `uniform (10 0 0);` i.e. *Ux* = 10*m/s*, and *U* = 0*m/s* respectively.
- The `frontAndBack` patch is given *type* `empty;`, indicating that no solution is required in that direction since the case is 2D.
- You should now be able to understand `0/p` also.
- The resulting time directories are similar but the `internalField` is now a `non uniform List<scalar>` containing the results. There is also a `phi` file, containing the resulting face fluxes that are needed to yield a perfect restart. There is also some time information in `0.*/uniform/time`. The `0.*/uniform` directory can be used for uniform information in a parallel simulation.

constant Directory

- The `transportProperties` file is a dictionary for the dimensioned scalar nu.
- The `turbulenceProperties` file is a dictionary for the turbulence simulation types.
- The **`polyMesh`** directory originally contains the mesh files using the **`blockMesh`** mesh generator, and now also the mesh in OpenFOAM format.

system Directory

- The **`system`** directory consists of set-up files such as:

```
blockMeshDict      controlDict      fvSchemes      fvSolution
```

- `blockMeshDict` contains instructions on how to generate the mesh.
- `controlDict` contains general instructions on how to run the case.
- `fvSchemes` contains instructions on which discretization schemes that should be used for different terms in the equations.
- `fvSolution` contains instructions on how to solve each discretized linear equation system. It also contains instructions for the PISO pressure-velocity coupling.

system Directory (controlDict)

- The *controlDict* dictionary consists of the following lines:

```
application     simpleFoam;
startFrom       startTime;
startTime       0;
stopAt          endTime;
endTime         2000;
deltaT          1;
writeControl    timeStep;
writeInterval   100;
purgeWrite      0;
writeFormat     ascii;
writePrecision  6;
writeCompression off;
timeFormat      general;
timePrecision   6;
runTimeModifiable true;
```

system Directory (controlDict)

- The following lines tells **simpleFoam** to start at startTime=0, and stop at endTime=2000, with a time step deltaT=1:

```
application     simpleFoam;
startFrom       startTime;
startTime       0;
stopAt          endTime;
endTime         2000;
deltaT          1;
```

system Directory (controlDict)

- The following lines tells **simpleFoam** to write out results in separate directories (`purgeWrite 0;`) every 100 `timeStep`, and that they should be written in `uncompressed` *ascii* format with *writePrecision* 6. *timeFormat* and *timePrecision* are instructions for the names of the time directories.

```
writeControl    timeStep;
writeInterval   100;
purgeWrite      0;
writeFormat     ascii;
writePrecision  6;
writeCompression off;
timeFormat      general;
timePrecision   6;
runTimeModifiable true;
```

- *runTimeModifiable yes;* allows you to make modifications to the case while it is running.

system Directory (fvScheme)

- The *fvSchemes* dictionary defines the discretization schemes, in particular the time marching scheme and the convections schemes:

```
ddtSchemes
{
    default         steadyState;
}

gradSchemes
{
    default         Gauss linear;
}

divSchemes
{
    default         none;
    div(phi,U)      bounded Gauss linearUpwind grad(U);

    turbulence      bounded Gauss limitedLinear 1;
    div(phi,k)      $turbulence;
    div(phi,epsilon) $turbulence;
    div(phi,omega)  $turbulence;

    div(nonlinearStress) Gauss linear;
    div((nuEff*dev2(T(grad(U))))) Gauss linear;
}
```

- Here we use the steady state scheme for time schemes, and Gauss linear scheme for Gradient schemes.
- *default none;* means that schemes must be explicitly specified.
- Find the available convection schemes using a **'dummy'** dictionary entry. There are 50 alternatives, and the number of alternatives are increasing!

system Directory (fvSolution)

- The *fvSolution* dictionary defines the solution procedure.
- The solutions of the ***p*** linear equation systems is defined by:

```
solvers
{
    p
    {
        solver          GAMG;
        tolerance       1e-06;
        relTol          0.1;
        smoother        GaussSeidel;
    }
```

- The ***p*** linear equation system is solved using the GAMG(Generalised geometric-algebraic multi -grid).
- The solution is considered converged when the residual has reached the *tolerance*, or if it has been reduced by *relTol* at each time step.

system Directory (fvSolution)

- The settings for the SIMPLE algorithm are specified in the SIMPLE entry:

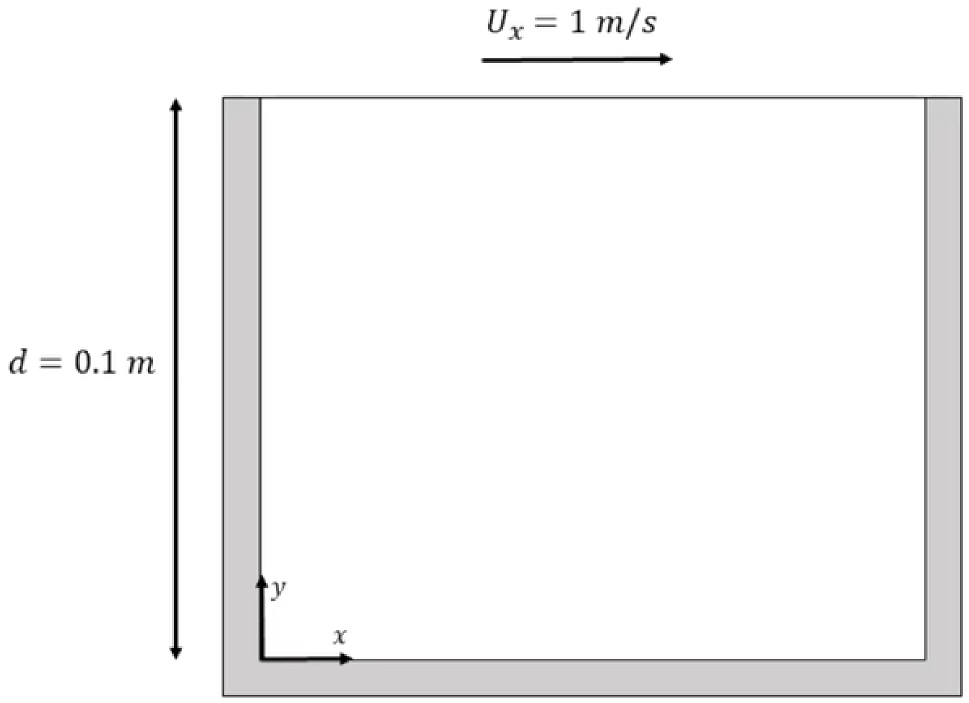
```
SIMPLE
{
    nNonOrthogonalCcorrectors 0;
    consistent      yes;

    residualControl
    {
        p               1e-2;
        U               1e-3;
        "(k|epsilon|omega|f|v2)" 1e-3;
    }
}
```

```
relaxationFactors
{
    equations
    {
        U               0.9;
        ".*"            0.9;
    }
}
```

- `consistent` changes SIMPLE algorithm to its consistent formulation, SIMPLEC.
- `residualControl` sets termination of the case, when the initial residual of the field equations falls below u
- `relaxationFactor` are applied to stabilize calculations by limiting the rate of change of both fields and equations.

OpenFoam example

Lid-driven Cavity Flow Case




```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212$ mkdir -p $FOAM_RUN
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212$ run
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run$ cp -r $FOAM_TUTORIALS/incompressible/icoFoam/cavity/cavity $FOAM_RUN/
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run$ cd $FOAM_RUN/cavity
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls
0  constant  system
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi system/blockMeshDict
```

```
FoamFile
{
    version     2.0;
    format      ascii;
    class       dictionary;
    object      blockMeshDict;
}
// * * * * * * * * * * * * * * * * * * * * * * * * *

scale   0.1;

vertices
(
    (0 0 0)
    (1 0 0)
    (1 1 0)
    (0 1 0)
    (0 0 0.1)
    (1 0 0.1)
    (1 1 0.1)
    (0 1 0.1)
);

blocks
(
    hex (0 1 2 3 4 5 6 7) (20 20 1) simpleGrading (1 1 1)
);

edges
```

```
boundary
(
    movingWall
    {
        type wall;
        faces
        (
            (3 7 6 2)
        );
    }
    fixedWalls
    {
        type wall;
        faces
        (
            (0 4 7 3)
            (2 6 5 1)
            (1 5 4 0)
        );
    }
    frontAndBack
    {
        type empty;
        faces
        (
            (0 3 2 1)
            (4 5 6 7)
        );
    }
```

```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212$ mkdir -p $FOAM_RUN
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212$ run
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run$ cp -r $FOAM_TUTORIALS/incompressible/icoFoam/cavity/cavity $FOAM_RUN/
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run$ cd $FOAM_RUN/cavity
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls
0  constant  system
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi system/blockMeshDict
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ blockMesh
```

blockMeshでmesh生成！

```
Creating polyMesh from blockMesh
Creating patches
Creating cells
Creating points with scale (0.1 0.1 0.1)
    Block 0 cell size :
        i : 0.005 .. 0.005
        j : 0.005 .. 0.005
        k : 0.01 .. 0.01

No patch pairs to merge

Writing polyMesh with 0 cellZones
----------------
Mesh Information
----------------
  boundingBox: (0 0 0) (0.1 0.1 0.01)
  nPoints: 882
  nCells: 400
  nFaces: 1640
  nInternalFaces: 760
----------------
Patches
----------------
  patch 0 (start: 760 size: 20) name: movingWall
  patch 1 (start: 780 size: 60) name: fixedWalls
  patch 2 (start: 840 size: 800) name: frontAndBack

End
```

meshing成功！

2:10 / 4:50

生成されている設定内容も一度確認可能

```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls constant/
polyMesh  transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi constant/transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls 0/
U  p
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/U
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/p
```

```
    object      U;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

dimensions      [0 1 -1 0 0 0 0];

internalField   uniform (0 0 0);

boundaryField
{
    movingWall
    {
        type            fixedValue;
        value           uniform (1 0 0);
    }

    fixedWalls
    {
        type            noSlip;
    }

    frontAndBack
    {
        type            empty;
    }
}


// ************************************************************************
```

```
    class       volScalarField;
    object      p;
}
// * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

dimensions      [0 2 -2 0 0 0 0];

internalField   uniform 0;

boundaryField
{
    movingWall
    {
        type            zeroGradient;
    }

    fixedWalls
    {
        type            zeroGradient;
    }

    frontAndBack
    {
        type            empty;
    }
}
```

```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls constant/
polyMesh  transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi constant/transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls 0/
U  p
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/U
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/p
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi system/controlDict
```

```
startTime       0;

stopAt          endTime;

endTime         0.5;

deltaT          0.005;

writeControl    timeStep;

writeInterval   20;

purgeWrite      0;

writeFormat     ascii;

writePrecision  6;

writeCompression off;

timeFormat      general;

timePrecision   6;

runTimeModifiable true;
```

```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls constant/
polyMesh  transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi constant/transportProperties
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls 0/
U  p
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/U
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi 0/p
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ vi system/controlDict
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ icoFoam
```

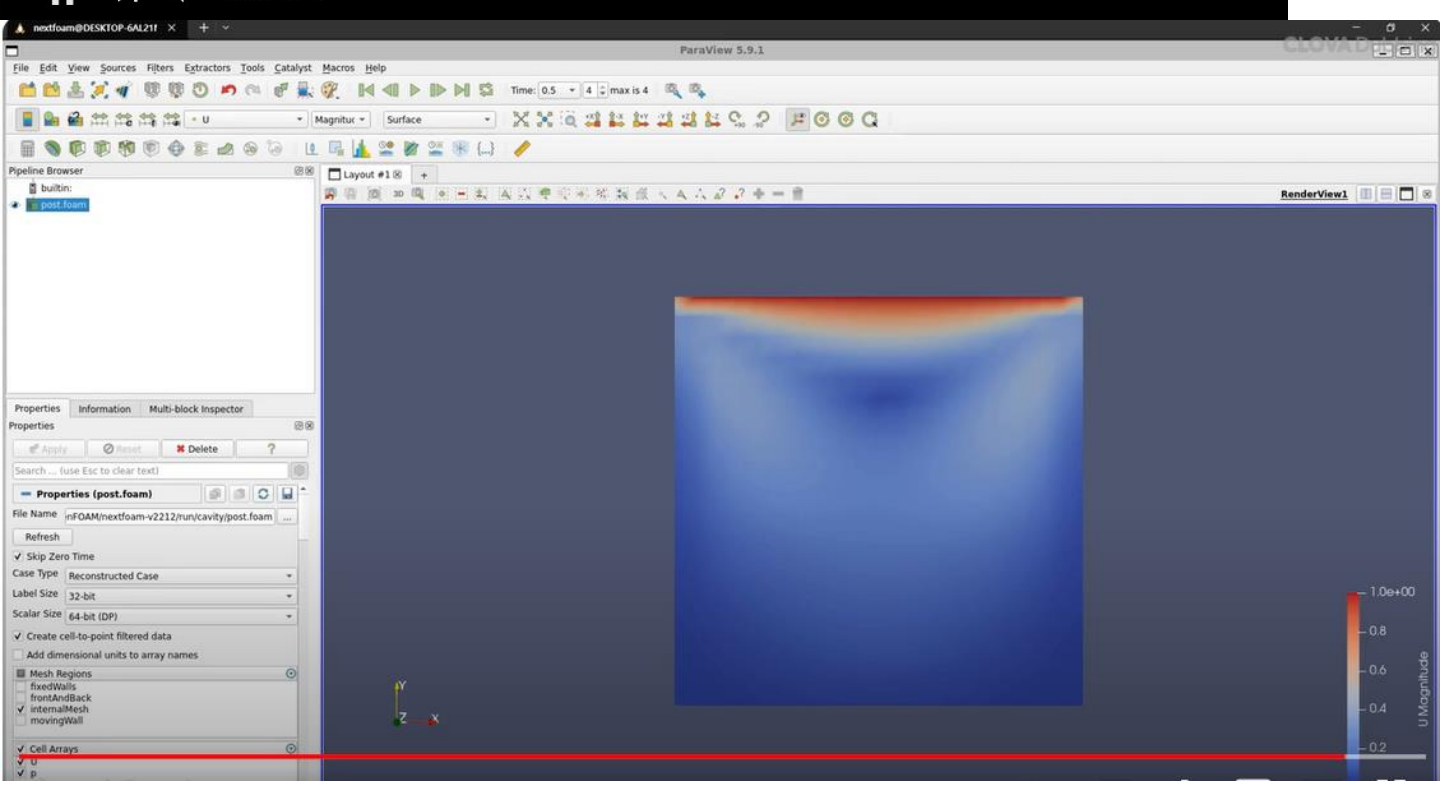
3:43 / 4:50

設定ファイル確認後、問題なければ、icoFoamで計算実行

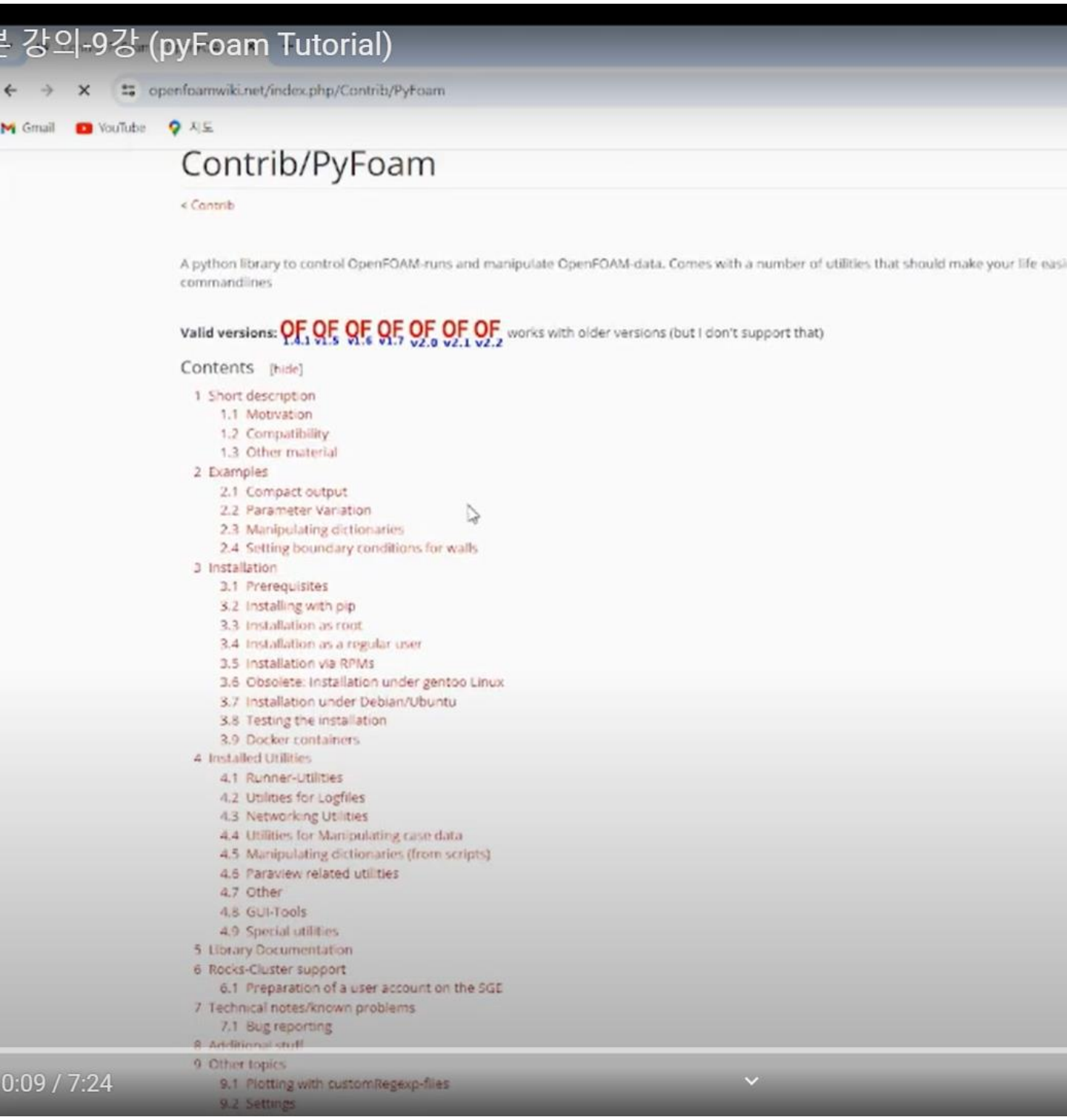
```
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ ls
0  0.1  0.2  0.3  0.4  0.5  constant  system
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ touch post.foam
nextfoam@DESKTOP-6AL21MN:~/OpenFOAM/nextfoam-v2212/run/cavity$ paraview post.foam
```

結果フォルダが作成されている

3:58 / 4:50



PYFOAM


본 강의-9강 (pyFoam Tutorial)
openfoamwiki.net/index.php/Contrib/PyFoam
Gmail
YouTube
지도
Contrib/PyFoam
< Contrib
A python library to control OpenFOAM-runs and manipulate OpenFOAM-data. Comes with a number of utilities that should make your life easi
commandlines
Valid versions: OF OF OF OF OF OF OF works with older versions (but I don't support that)
Contents [hide]
1 Short description
1.1 Motivation
1.2 Compatibility
1.3 Other material
2 Examples
2.1 Compact output
2.2 Parameter Variation
2.3 Manipulating dictionaries
2.4 Setting boundary conditions for walls
3 Installation
3.1 Prerequisites
3.2 Installing with pip
3.3 Installation as root
3.4 Installation as a regular user
3.5 Installation via RPMs
3.6 Obsolete: Installation under gentoo Linux
3.7 Installation under Debian/Ubuntu
3.8 Testing the installation
3.9 Docker containers
4 Installed Utilities
4.1 Runner-Utilities
4.2 Utilities for Logfiles
4.3 Networking Utilities
4.4 Utilities for Manipulating case data
4.5 Manipulating dictionaries (from scripts)
4.6 Paraview related utilities
4.7 Other
4.8 GUI-Tools
4.9 Special utilities
5 Library Documentation
6 Rocks-Cluster support
6.1 Preparation of a user account on the SGE
7 Technical notes/known problems
7.1 Bug reporting
9 Other topics
9.1 Plotting with customRegexp-files
9.2 Settings
0:09 / 7:24

narnia.ai

"젊은부부는 역시... Best Mechanical En... 新しいタブ (6)【革命的すぎ】プロ... (6) ChatGPTでブログ... (6) Introduction to... (6) AI アニメーション ジ... (6) ChatGPTをプログラ... Netflix

NARNIA LABS AslanX Solution Resource Company EN Get Started

AI for CAE

Engineer the Future: AI-Powered Product Design

The generative AI platform for manufacturing, AslanX simplifies the repetitive processes of design, simulation, and testing

Product inquiry

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사업화 성과

- 2023.12: LG 이노텍 & Tech-Blaze 선정
- 2023.11: LG 슈퍼스타트 인큐베이트 2기 선정
- 2023.10: Korea AI Start Up 100 선정
- 2023.05: 현대자동차그룹, TS인베스트먼트, 삼양화학, 김기사랩, 라구나 **Pre-A 투자 유치 (누적 37억)**
- 2023.05: 글로벌 기업 협업 (Ansys - ASK 프로그램) 선정 **(최우수기업)**
- 2022.10: K-테크 스타트업 왕중왕전 **대상**
- 2022.09: TIPS 선정
- 2022.08: 현대자동차그룹(제로원) **시드 투자**
- 2022.06: 예비창업패키지 선정 **(최우수기업)**
- **2022.04: 법인설립** (KAIST 교원창업)
- 2021.11: KAIST E*5 Lab Startup **1위**

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최우수상, 대상 등등 1등만 많이 해왔습니다

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팀원

KAIST MICHIGAN HYUNDAI

강남우 (CEO)

- 현) KAIST 모빌리티대학원 부교수
- 전) 현대자동차 연구원
- 미시간대학 디자인사이언스 박사
- 서울대 기술경영 석사
- 서울대 기계항공 학사
- AI 기반 설계 연구 국제적 선도
- 국제/국내 다수 수상 경력

석박사급 70%

- 박사과정 이상 – 23%
- 석사과정 이상 – 47%
- 학사이상 – 30%

산업경험 85%

- 마이크로소프트, 현대자동차
- LG화학, 삼성전자, 두산인프라코어
- 알테어, 지멘스, MSC
- 쎄트렉아이, 에스아이에이
- 이랜드, 롯데정보통신
- 배달의민족, VUNO
- Kali Care, Globaleur
- EUCLID, IBRICKS, 비사이드, 비브스튜디오
- ...

분야별 전문가

- AI/설계 연구 – 42%
- SW 개발 – 29%
- 경영/기획/디자인 – 29%

오피스는 있지만 풀재택!

★ 제주 오피스

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54

85% 에 해당하는 분들이 다 산업 경험을 하고 오셨습니다

Predictive AI - (1) Non-parametric Prediction

Parametric prediction

Training

x_1

x_2

$[x_1, x_2]$ $y = f(x_1, x_2)$

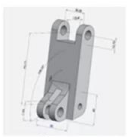
Inference

Possible

Impossible

Impossible

$[x_1, x_2]$ $y = f(x_1, x_2)$



<Simple and parameterizable shapes>

Non-parametric prediction

Training

Feature Extraction

$[\mathbf{z}]$ $y = f(\mathbf{z})$

Inference

Possible

Possible

Possible

Feature Extraction

$[\mathbf{z}]$ $y = f(\mathbf{z})$

<Complex and non-parameterizable shapes>

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다양한 형상에 대해서 입력으로 넣을 수 있게 됩니다

Predictive AI - (2) Field Prediction

Scalar prediction

Inference

Feature Extraction

$[\mathbf{z}]$ $y = f(\mathbf{z})$

Scalars

Maximum Stress

Maximum Displacement

Drag Coefficient

$4 \times 2 \times k \phi$

Field prediction

Inference

Feature Extraction

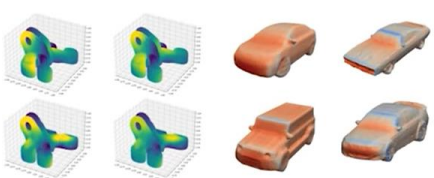
$[\mathbf{z}]$ $\mathbf{y} = f(\mathbf{z})$

Fields

Stress Field

Displacement Field

Pressure Field



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굉장히 고차원의 값들을 예측을 해야 됩니다

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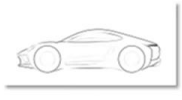
Predictive AI - (3) Multimodal Prediction

3D Shapes (CAD)

2D Images



1D Parameters

$4 \times 2 \times k \phi$

$[\mathbf{z}_1]$

$[\mathbf{z}_2]$

$[\mathbf{z}_3]$

AI

$\mathbf{y} = f(\mathbf{z})$

Prediction

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하지만 딥러닝을 사용하면 여러분들이 3D 캐드도 갖고 있고

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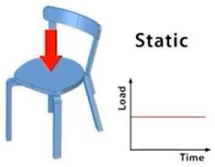
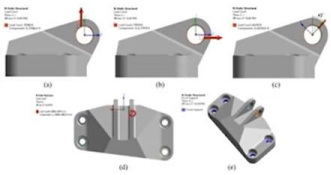
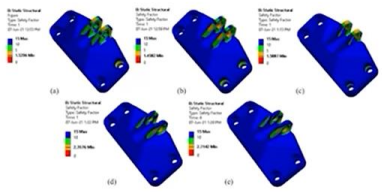
Predictive AI - (4) Dynamic Prediction

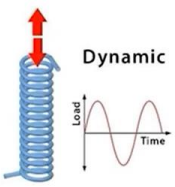
Static prediction

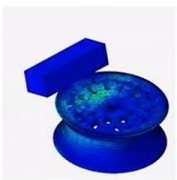






Dynamic prediction





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모든 시간 그 도메인 상에서 우리의 제품이 어떤 거동을 하는지

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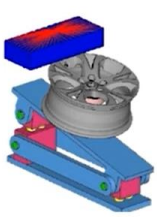
Predictive AI - (5) Multi-fidelity Prediction

Closer to the Real-world



Calibration

Low-fidelity

- Cheap
- Approximated
- CAE simulation
- 1-D modeling

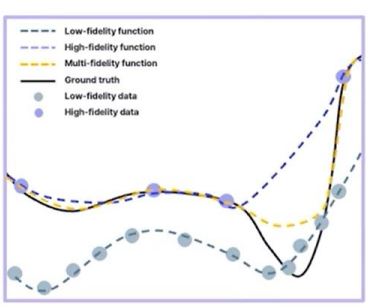
High-fidelity

- Expansive
- Accurate
- Test results
- Detailed simulation

Current simulations fall short of mirroring real-world phenomena due to a lack of comprehensive data for accurate model training.

Efficient prediction models

Our models merge vast quantities of affordable approximations with high-value real data for efficient and precise predictions.



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로우 피델리티 데이터와 하이 피델리티 데이터를 동시에 사용할 수 있다는 겁니다

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Predictive AI - (5) Multi-fidelity Prediction

Closer to the Real-world

Calibration

Low-fidelity

- Cheap
- Approximated
- CAE simulation
- 1-D modeling

High-fidelity

- Expansive
- Accurate
- Test results
- Detailed simulation

Current simulations fall short of mirroring real-world phenomena due to a lack of comprehensive data for accurate model training.

Efficient prediction models

Our models merge vast quantities of affordable approximations with high-value real data for efficient and precise predictions.

Low-fidelity function
High-fidelity function
Multi-fidelity function
Ground truth
Low-fidelity data
High-fidelity data

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그렇게 해서 나오는 장점은 보통은 하이 피델리티 데이터는 모으기 어렵기 때문에

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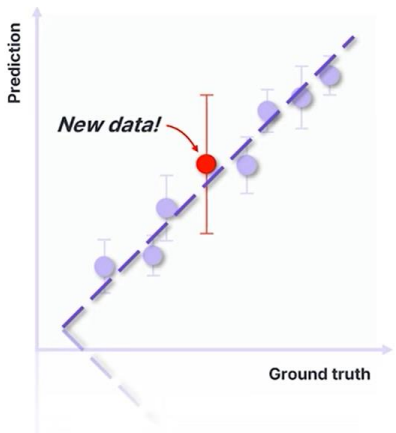
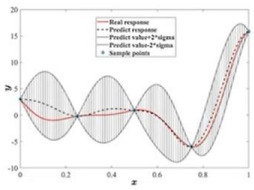
Predictive AI - (6) Uncertainty Quantification & Adaptive Sampling



Confidence Insights

Our model provides reliability scores for its forecasts on novel samples, ensuring informed decision-making.



Continual Improvement (Active Learning)

Incorporate low-confidence s
to refine and elevate your mo

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단순히 예측한 값을 믿는 게 아니라 그 신뢰도를 보고 이 값은 믿을 수 있구나

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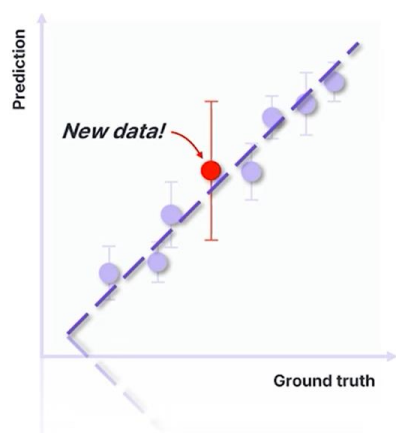
Predictive AI - (6) Uncertainty Quantification & Adaptive Sampling



Confidence Insights

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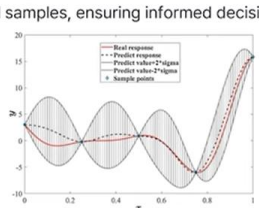

Continual Improvement (Active Learning)

Incorporate low-confidence s
to refine and elevate your mo

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불확실한 부분만 데이터를 더 모아서 모델의 성능을 가장 소량의 데이터로도

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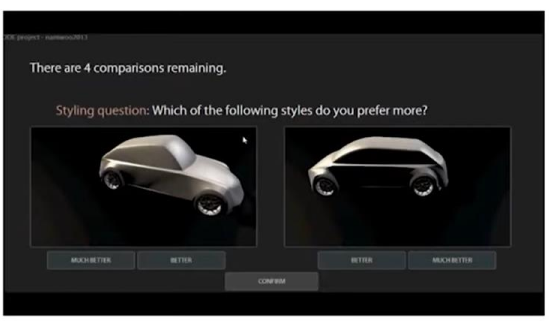
Predictive AI - (7) Customer Preference Prediction

Design for Market Systems



Informed Planning & Design

Equip your development process with a deep understanding of consumer expectations, ensuring your products resonate more effectively with the target audience.

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공학적인 성능 데이터뿐만 아니라 고객의 감성 데이터도 학습이 가능하다는 겁니다

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Generative AI - (1) Non-parametric Design Optimization

When CAE data is not available

① Generation + CAE + Optimization

<Generation>

<CAE>

When CAE data is sufficient

② Generation + Surrogate Model + Optimization

<Generation>

<Surrogate Model>

Optimization

Performance 2

Performance 1

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첫째 Non-parametric한 최적 설계가 가능하다

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Generative AI - (1) Non-parametric Design Optimization

When CAE data is not available

① Generation + CAE + Optimization

<Generation>

<CAE>

When CAE data is sufficient

② Generation + Surrogate Model + Optimization

<Generation>

<Surrogate Model>

Optimization

Performance 2

Performance 1

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① 그러면 그냥 바로 CAE solver에 물려서 CAE를 해가면서 좋은 설계를 찾는 겁니다

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Generative AI - (1) Non-parametric Design Optimization

When CAE data is not available

① Generation + CAE + Optimization

<Generation>

<CAE>

When CAE data is sufficient

② Generation + Surrogate Model + Optimization

<Generation>

<Surrogate Model>

Optimization

Performance 2

Performance 1

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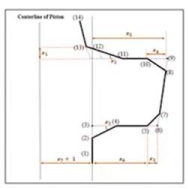
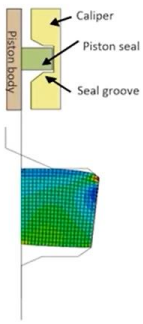
② 두 번째 방법은 설계도 있고 내가 CAE 데이터도 충분하다

Generative AI - (2) Real-time Optimization

Deep Learning-based Inverse Design



Design
(X)



Performance
(Y)

Design
(X)

Prediction
$Y = f_F(X)$

Performance
(Y)

Target Performance
(Y)

$X = f_I(Y)$
Real-time
Inverse Design

Optimal Design
(X*)

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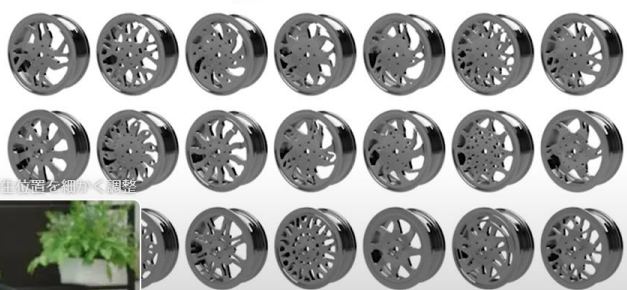
그래서 이렇게 인벌스한 방법으로 Y는 f(X)를 학습하는 게 아니라

1달 걸리던 부품 설계가 1분만에 끝?? 제조업 설계에 AI가 함께 하면 벌어지는 놀라운 일들

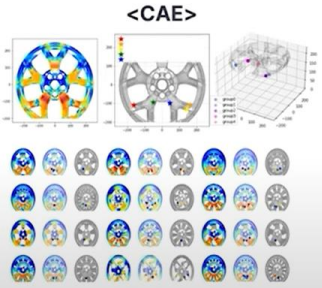
Generative AI - (3) Synthetic Data Generation

Data Generation for Training Predictive AI

<Synthetic Data>



<CAE>



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AI가 설계 디자인에 필요한 이유

1:37

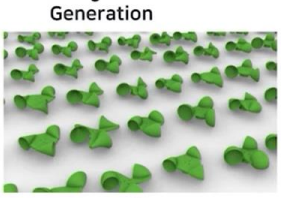
그 합성 데이터를 해석해서 해석한 결과를 얻는 것이 필요합니다

14:51 / 39:57 • AI로 해결하고 싶은 문제 ›

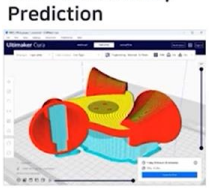
Generative AI - (4) Generative Design for Manufacturing

① Additive Manufacturing

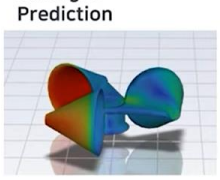
Design
Generation



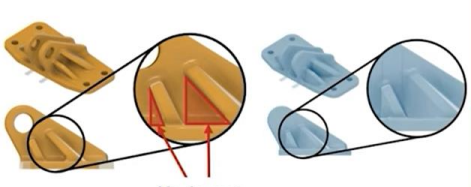
Manufacturability
Prediction



Strength
Prediction

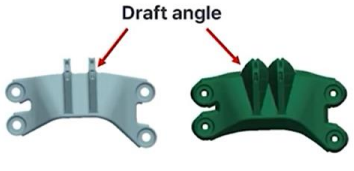


② Casting and Injection Molding



Undercut

Draft angle



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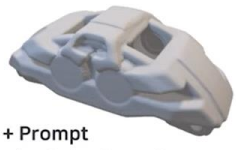
이런 것들을 고려해 가면서 생성도 가능합니다

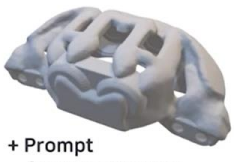
AGORA SUPERSTART

Generative AI - (5) Realistic Rendering for Customer Feedback

+ Prompt
[A concept design for steel wheel, matte finish type ···



+ Prompt
[car brake caliper, red···



+ Prompt
[car brake caliper, blue···

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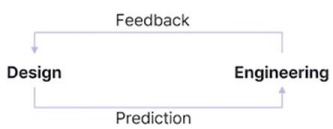
그래서 나의 CAD에 실시간 렌더링을 해서 고객에게 가져다 주고

AGORA SUPERSTART

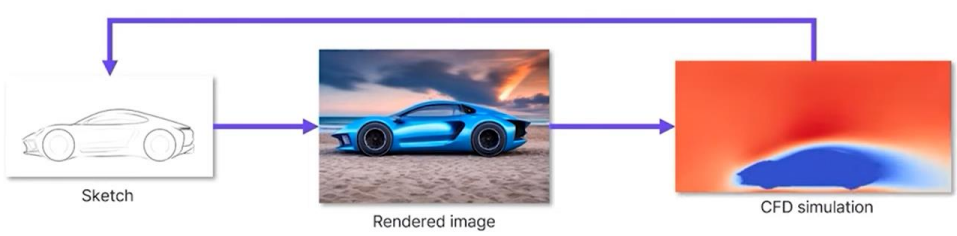
Generative AI - (6) Integration of Design and Engineering



Superior Design from the Start

Ensure that your initial designs are not just innovative but also viable, laying a strong foundation for the entire development process.

70-80% of a vehicle's aerodynamic performance is shaped during the **styling phase**.



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렌더링 동시에 또 유체해석 CFD 시뮬레이션을 해서

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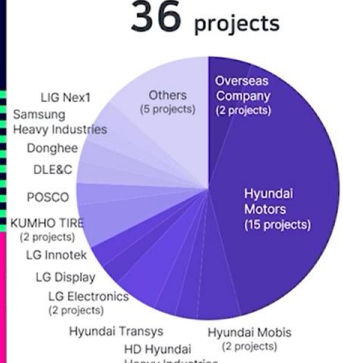
적용 사례

제조 현장에서 기술력 검증 및 노하우 축적



Completed or On-going

Mobility

HYUNDAI KUMHO TIRE HYUNDAI MOBIS posco HYUNDAI TRANSYS DONGHEE

Electronics

LG Electronics LG Display LG Innotek LS ELECTRIC

Heavy industry and others

HD HYUNDAI HEAVY INDUSTRIES SAMSUNG HEAVY INDUSTRIES LIG Nex1 IDL E&C

Under discussion

VW brembo KTM SAMSUNG HD HYUNDAI ELECTRIC Hanwha Systems HYUNDAI Rotem HWASHIN ⋮

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현재 총 36개의 프로젝트들을 수행해 왔고요

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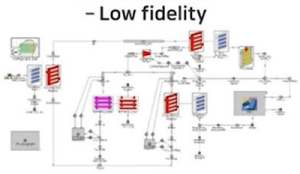
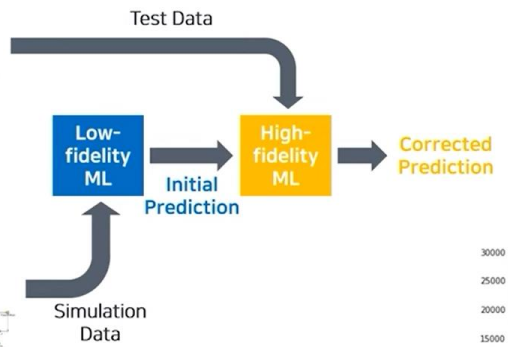
적용 예시 – 에어컨 온도 예측

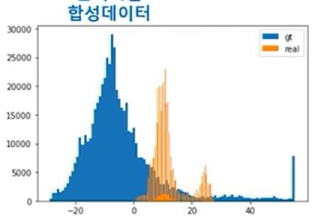
Test Data
– High fidelity

Simulation Data
– Low fidelity





물리기반 합성데이터



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하이 피델리티 모델이 9.7도 정도 되겠구나 라고 예측을 하는 거죠

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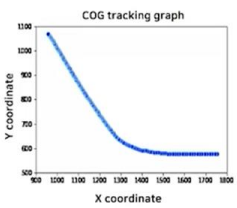
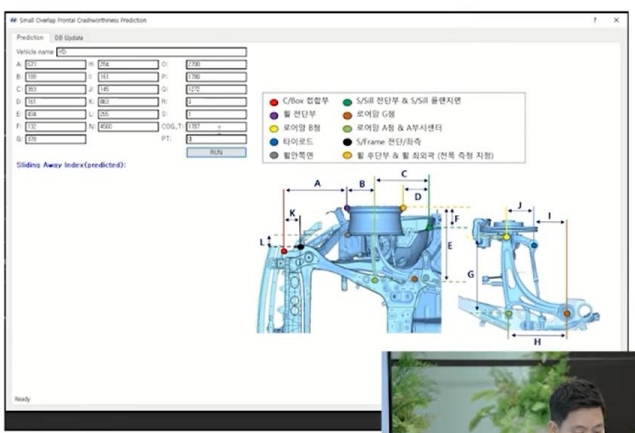
적용 예시 – 차량 충돌 거동 예측





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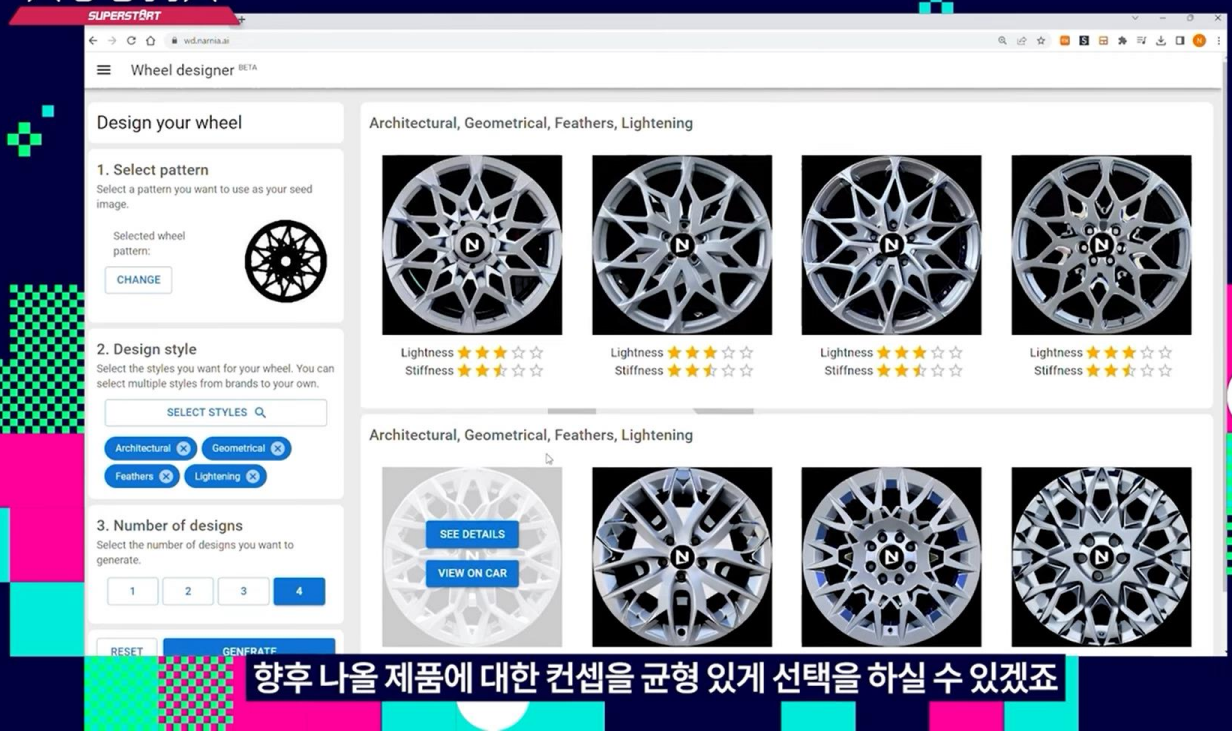
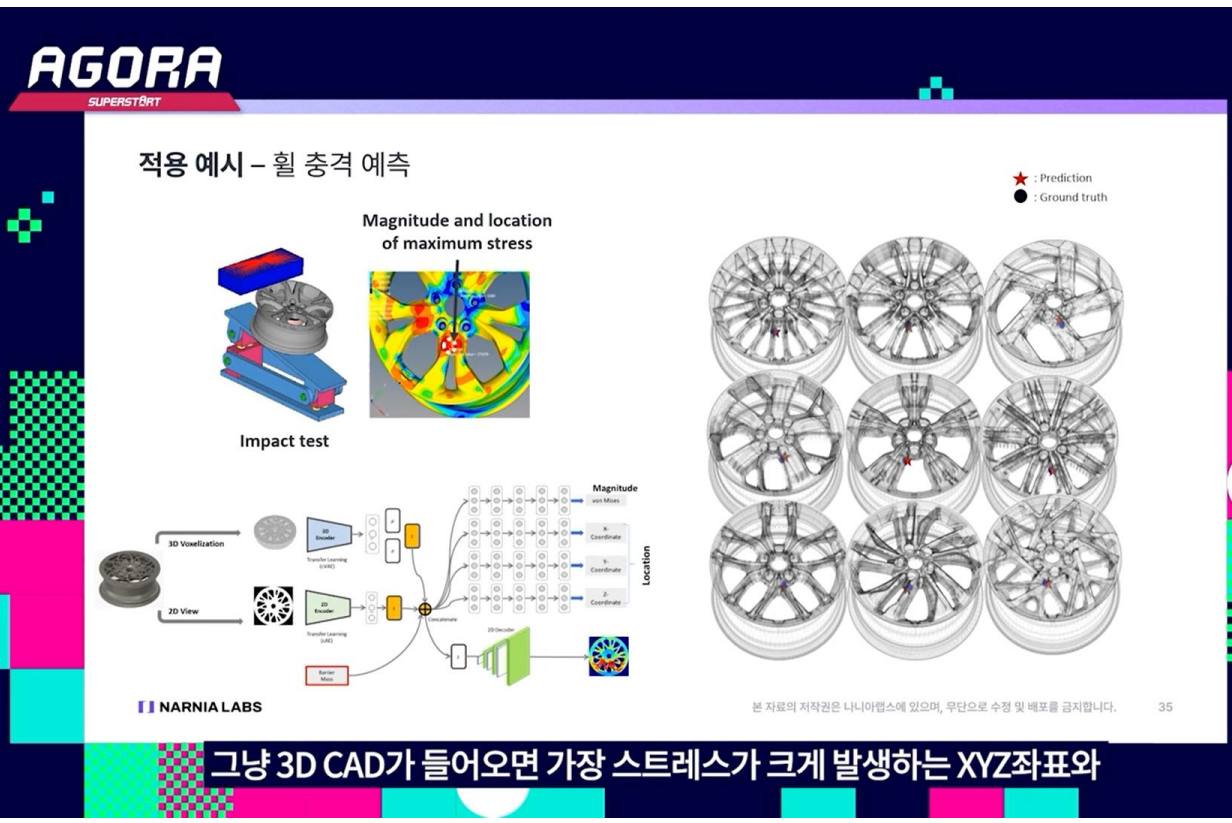
이 차량의 지오메트리를 알기 때문에 그 지오메트리와 거동 간의 관계를 학습하면



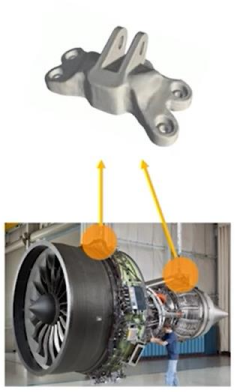
향후 나올 제품에 대한 컨셉을 균형 있게 선택을 하실 수 있겠죠

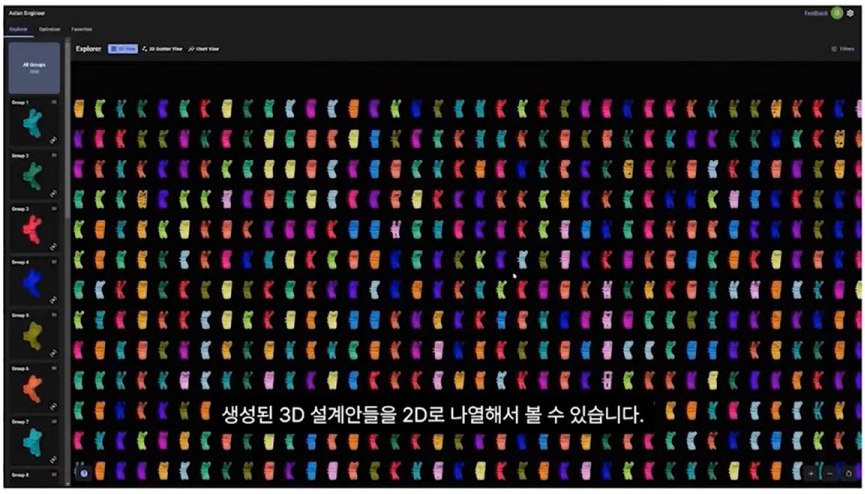


그냥 3D CAD가 들어오면 가장 스트레스가 크게 발생하는 XYZ좌표와

AGORA SUPERSTART

적용 예시 – 비행기 엔진 브라켓 설계





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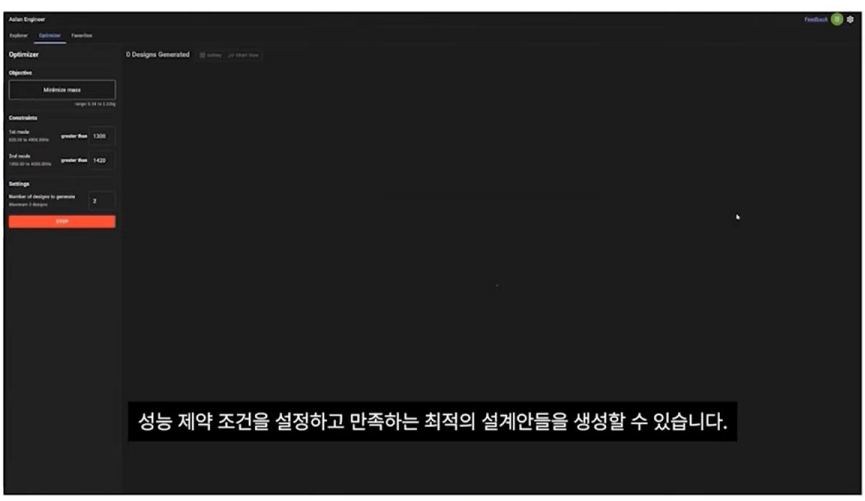
제트엔진에 들어가는 브라켓을 다음과 같이 3D 딥러닝으로

AGORA SUPERSTART

적용 예시 – 비행기 엔진 브라켓 설계



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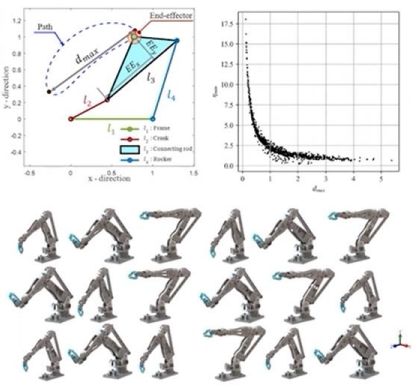
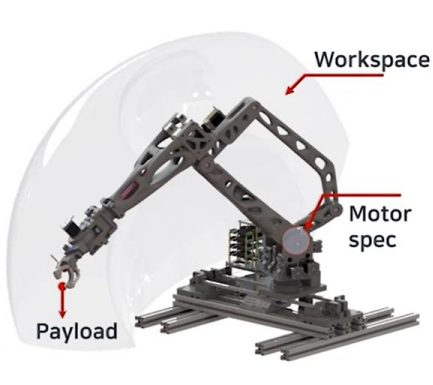
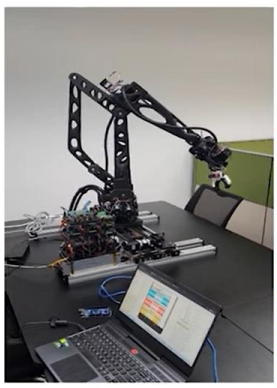
본 자료의 저작권은 나니아랩스에 있으며, 무단으로 수정 및 배포를 금지합니다.
36

그리고 타겟 성능을 넣어주면 바로 이렇게 실시간 역설계를 해줍니다

적용 예시 – 로봇 설계







거기에 맞는 최적화된 링크를 설계를 하는 겁니다

AGORA SUPERSTART

제품

제조업 제품개발에 특화된 AI SW

Aslan X

도메인 전문가가
설계문제를 해결하기 위해
최신 AI 모델을 쉽게 학습 및 배포할 수 있는
Low-code AI Platform

생성 AI | 평가 AI | 최적화 AI | 추천 AI

학습 → 배포

Web APP

Plugin

CAD/CAE

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생성할 수 있는 AI, 평가할 수 있는 AI, 최적화할 수 있는 AI, 추천할 수 있는 AI

AGORA SUPERSTART

제품

제조업 제품개발에 특화된 AI SW

Aslan X

도메인 전문가가
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생성 AI | 평가 AI | 최적화 AI | 추천 AI

학습 → 배포

Web APP

Plugin

CAD/CAE

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본 자료의 저작권은 나니아랩스에 있으며, 무

API 형태로 되어 있다고 쉽게 생각을 하시면 되고요

AGORA SUPERSTART

제품

제조업 제품개발에 특화된 AI SW

Aslan X

도메인 전문가가
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Low-code AI Platform

생성 AI | 평가 AI | 최적화 AI | 추천 AI

학습 → 배포

Web APP

Plugin

CAD/CAE

NARNIA LABS

본 자료의 저작권은 나니아랩스에 있으며, 무

상용 소프트웨어에 탑재해서 사용을 하실 수 있게 되는 겁니다

AGORA SUPERSTART

사업화 성과

- 2023.12: LG 이노텍 & Tech-Blaze 선정
- 2023.11: LG 슈퍼스타트 인큐베이트 2기 선정
- 2023.10: Korea AI Start Up 100 선정
- 2023.05: 현대자동차그룹, TS인베스트먼트, 삼양화학, 김기사랩, 라구나 **Pre-A 투자 유치 (누적 37억)**
- 2023.05: 글로벌 기업 협업 (Ansys - ASK 프로그램) 선정 **(최우수기업)**
- 2022.10: K-테크 스타트업 왕중왕전 **대상**
- 2022.09: TIPS 선정
- 2022.08: 현대자동차그룹(제로원) **시드 투자**
- 2022.06: 예비창업패키지 선정 **(최우수기업)**
- **2022.04: 법인설립** (KAIST 교원창업)
- 2021.11: KAIST E*5 Lab Startup **1위**

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최우수상, 대상 등등 1등만 많이 해왔습니다

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팀원

KAIST · HYUNDAI

강남우 (CEO)

- 현) KAIST 모빌리티대학원 부교수
- 전) 현대자동차 연구원
- 미시간대학 디자인사이언스 박사
- 서울대 기술경영 석사
- 서울대 기계항공 학사
- AI 기반 설계 연구 국제적 선도
- 국제/국내 다수 수상 경력

석박사급 70%

- 박사과정 이상 – 23%
- 석사과정 이상 – 47%
- 학사이상 – 30%

산업경험 85%

- 마이크로소프트, 현대자동차
- LG화학, 삼성전자, 두산인프라코어
- 알테어, 지멘스, MSC
- 쎄트렉아이, 에스아이에이
- 이랜드, 롯데정보통신
- 배달의민족, VUNO
- Kali Care, Globaleur
- EUCLID, IBRICKS, 비사이드, 비브스튜디오

...

분야별 전문가

- AI/설계 연구 – 42%
- SW 개발 – 29%
- 경영/기획/디자인 – 29%

오피스는 있지만 풀재택!

★ 제주 오피스

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85% 에 해당하는 분들이 다 산업 경험을 하고 오셨습니다

当社からのお知らせ

NEW

2024/05/08 — お知らせ
【メディア掲載】AI総研にRICOSの事業が掲載されました

2024/04/18 — お知らせ
ダイクレが自律的に最適形状を探索するツール「 RICOS Generative CAE」を導入しアンカーパネルの設計工程の自動化・効率化を推進

2024/04/12 — お知らせ
【メディア掲載】Lumii Discoverに代表取締役 井原遊のインタビュー記事が掲載されました

AI とシミュレーション技術で製品設計の効率化と高付加価値化を実現する株式会社RICOS（本社: 東京都千代田区、代表取締役 井原遊、以下 RICOS）は、2024年4月から株式会社ダイクレ（本社: 広島県呉市、代表取締役社長 山本貴、以下 ダイクレ）に、「自律的に製品形状を変更、最適形状を探索するツール（Generative CAEツール）」である「RICOS Generative CAE」の提供を開始しました。

■導入の背景
ダイクレは、業界シェア1位を誇るグレーチングの製造・販売を主とした総合建材メーカーです。
今回 RICOS Generative CAE が活用されるのは、ダイクレの製品ラインナップの一つであるアンカーパネルの設計工程です。アンカーパネルは、FRP製格子状パネルに鋼製フレームを組み合わせた複合型受圧板で、切土のり面の補強工法の一種であるグラウンドアンカー工法に使用される法面製品です。アンカーパネルは開口率が約70%と高く、通水性や緑化に優れることから、多くの現場に採用されてきました。

現在サポートしている機能

・CADモデルからメッシュファイルを生成
・解析条件の付与
・解析結果の可視化
・構造解析
・熱解析
・固有値解析

今後サポートする予定の機能

・RICOS Mesh：品質のよいメッシュの作成
・OpenFOAM による流体解析

シミュレーションエンジニアの募集要項

業務について

● 業務内容

1. 外部案件におけるシミュレーションプロジェクトの遂行
2. シミュレーション環境の整備
3. 各種シミュレーションツールの調査
4. C++、Python によるシミュレーションデータの解析

株式会社RICOS について

RICOSは、ものづくりのプロセスを最適化するテックカンパニーです。2021年10月に、シリーズAラウンドとなる約3.0億円の資金調達を完了しました。
現在は、SaaS型CAEプラットフォーム「RICOS Production Suite」の公開に向け、研究・開発を推進しています。既存のCAEツールと異なる点として、下記のような特徴を備えています。
・CAEの工程がブラウザ上で完結する
・独自の高品質メッシャーを搭載
・独自の機械学習アルゴリズムを搭載
ツールの完成、および独自機能の性能向上に向けて、RICOSでしか取り組めない課題があります。新しい問題に対して積極的に取り組むことのできる方と共に研究・開発が進められることを楽しみにしております。

本社
東京都千代田区丸の内二丁目３番２号

売上高
1.1億円未満

従業員数
11〜50

RICOS Production Suite

≡ ログアウト

● 必要スキル

1. 流体（特に、非圧縮性流れ・圧縮性流れ・熱流体）の物理シミュレーションに関する知見
2. C++、Python のいずれかを用いてシミュレーションの入力データ作成、結果解析等を行った経験
3. OpenFOAM の使用経験

● 歓迎スキル

1. CAD ソフトウェアで形状を作成し、メッシュを生成し、シミュレーションまで行える技術
2. シミュレーションに関する研究開発経験
3. 機械学習への興味・経験

・想定年収 600 - 800 万円 / 年（30 時間/週、月給制）

在宅（リモートワーク）での勤務。必要な場合のみオフィス（東京都千代田区）への出社があります。

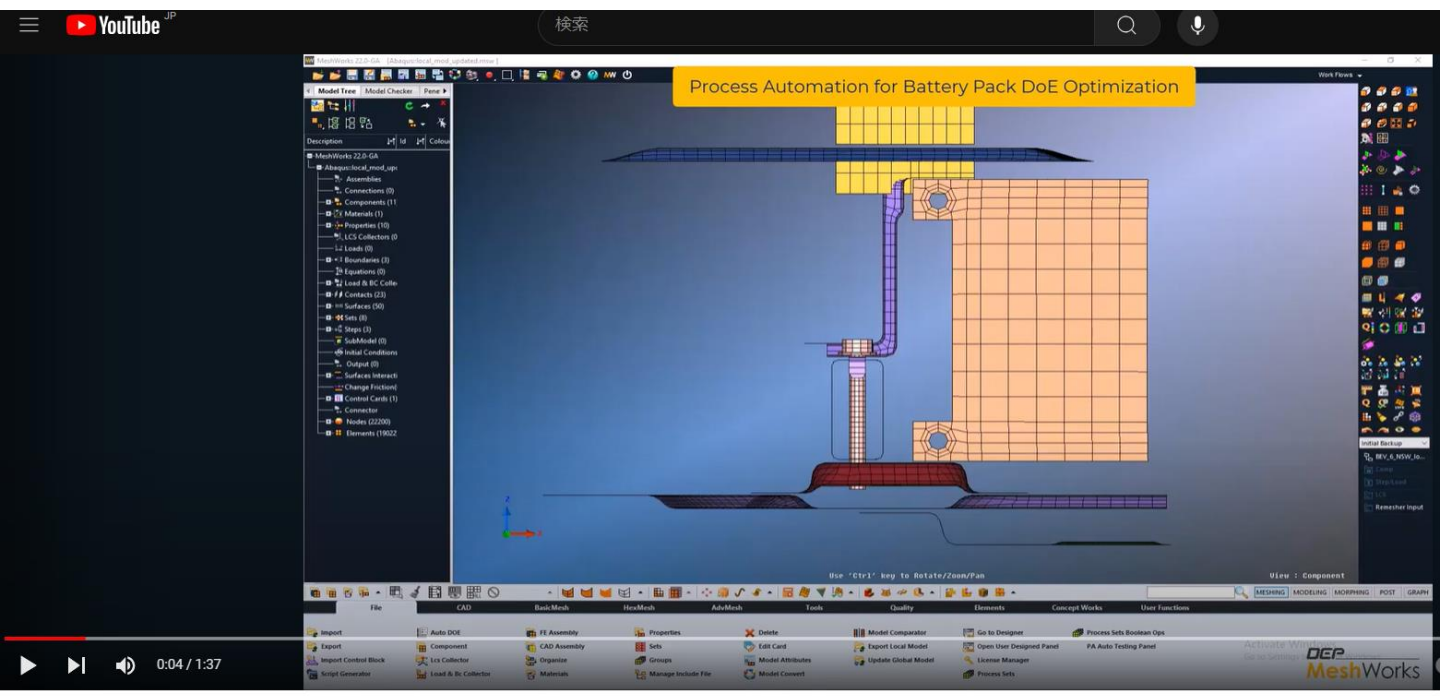
● 勤務時間

・完全フレックスタイム制（就業規則は、6 時間/日・120 時間/月です。雇用契約によって調整できます。）
・裁量労働制
のいずれかの選択制です。副業としての勤務も歓迎いたします。

● 筆記 & プログラミング試験

対象職種：コンサルティングエンジニア、バックエンドエンジニア、Pythonエンジニア、機械学習リサーチャー、シミュレーションエンジニア

想定所要時間1 〜 2日程度の試験を、問題の送付より1週間で解答いただきます。
応募を受け付けてから2営業日以内に問題を送付いたしますので、問題の解答に時間が取れるタイミングでご応募ください。解答の提出は弊社の GitLab サーバ上で行っていただきます。Git や GitLab に習熟していない方は、事前に使用方法をお調べいただくことをおすすめいたします。



Streamline your CAE workflow with #DEP's Process Automation Module in #MeshWorks

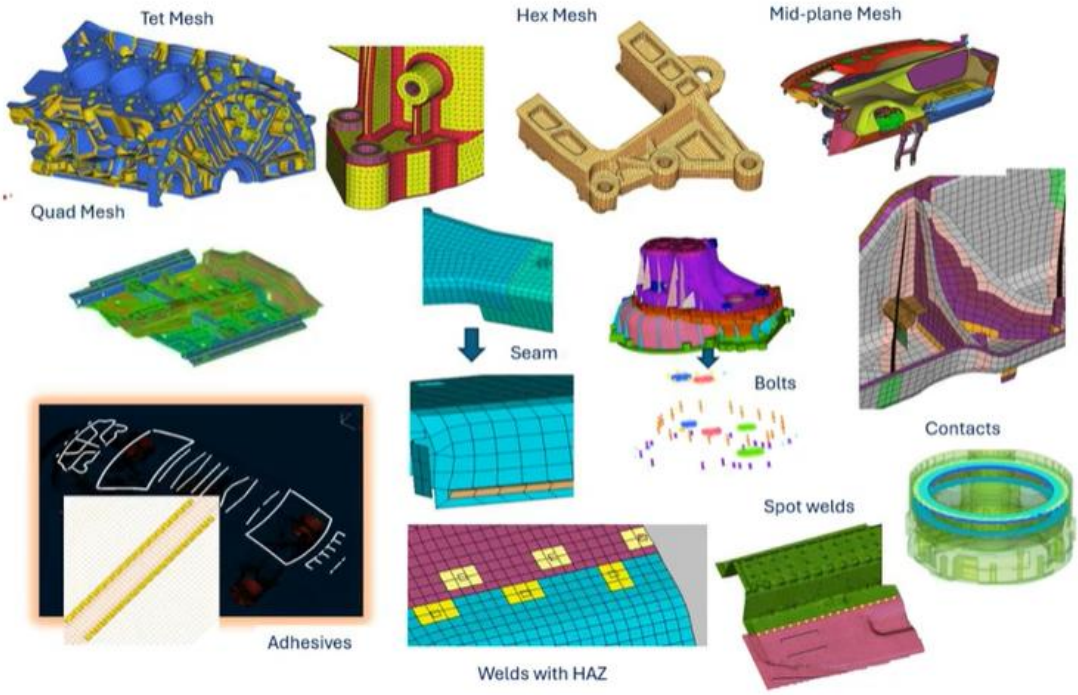
Detroit Engineered Products USA
チャンネル登録者数 739人

チャンネル登録 | 2 | 共有 | オフライン | 保存

すべて | シリーズの動画 | 提供: Detroit Engine

MeshWorks 2024 Webinar

Rapid Meshing & Modeling



NEW! Innovative ROM Module
NEW! Productive Electrification Module
Highly automated process workflows
Groundbreaking Concept Modeling
Intelligent AI/ ML CAE framework
Next generation CAD/CAE Morphing
Advanced Post processing
Cutting- edge CAE parametrization
Rapid Meshing & Modeling
Time saving MDO

Rapid Meshing

What is the value position for MeshWorks Users?

- Significant improvement in CAD Clean-up which in turn reduces the time required for post mesh correction drastically.
- Element quality is improved significantly compared to other tools in the market - again reduces meshing TAT (turn-around-time) in a big way.
- All types of superior meshing under one roof - tetra, hexa, plastics, sheet metal etc.
- Significant cost & time benefits - no need for multiple software for meshing.
- The total meshing time is reduced by 30% to 50% across various types without compromising on mesh quality.

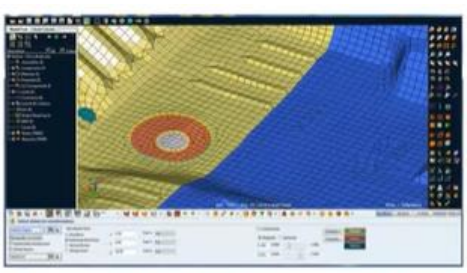
MeshWorks - Process Automation

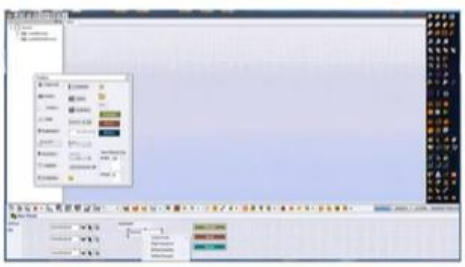
STEP:1
Record Advanced USER process using MSF.

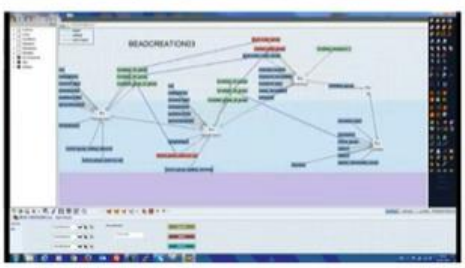
STEP:2
Create UI panel for Variables.

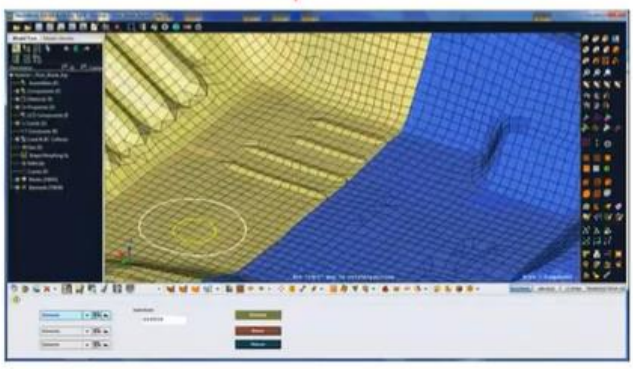
STEP:3
Plumbing the Process with UI, and Publish the Resource File.

STEP:4
Executing the Function using ProcessAuto User Panel









CAEを取り巻く課題 - “2025年の崖”と”CAE”

経済産業省が2018年に発表したDXレポートでもあるとおり、2025年までにDX（デジタルトランスフォーメーション）が進まない場合、最大で年間12兆円の経済損失が生じる可能性がある

情報元：経済産業省「DXレポート」より

残り3年! DX推進は急務です!!

CAEとAI/機械学習に関する講演数　推移

■2018 ■2019 ■2020 ■2021 ■2022

情報元：「自動車技術に関するCAEフォーラム」より

CAEツール定着のためのAI活用法　- CAEとAI編 -

DEP Japan株式会社
チャンネル登録者数 42人

登録済み

CAEを取り巻く課題 – CAEを活用する上での課題は？

- 人的確保
- スキルの習得に時間がかかる
- スキルの定着
- CAE活用の浸透
- ソフト維持管理コスト
- CAEを活用できる人材の育成
- コスト・労力（期間）に対するアウトプット価値
- CAE専任者以外でも扱えるCAEツール
- ライセンス費用
- CAEを活用できる体制の構築
- 計算コスト

人材不足
育成

コスト

ツール定着

情報元：「第12回自動車技術に関するCAEフォーラム2021オンライン」開催後報告書より

CAEを取り巻く課題

予算
維持費

コスト

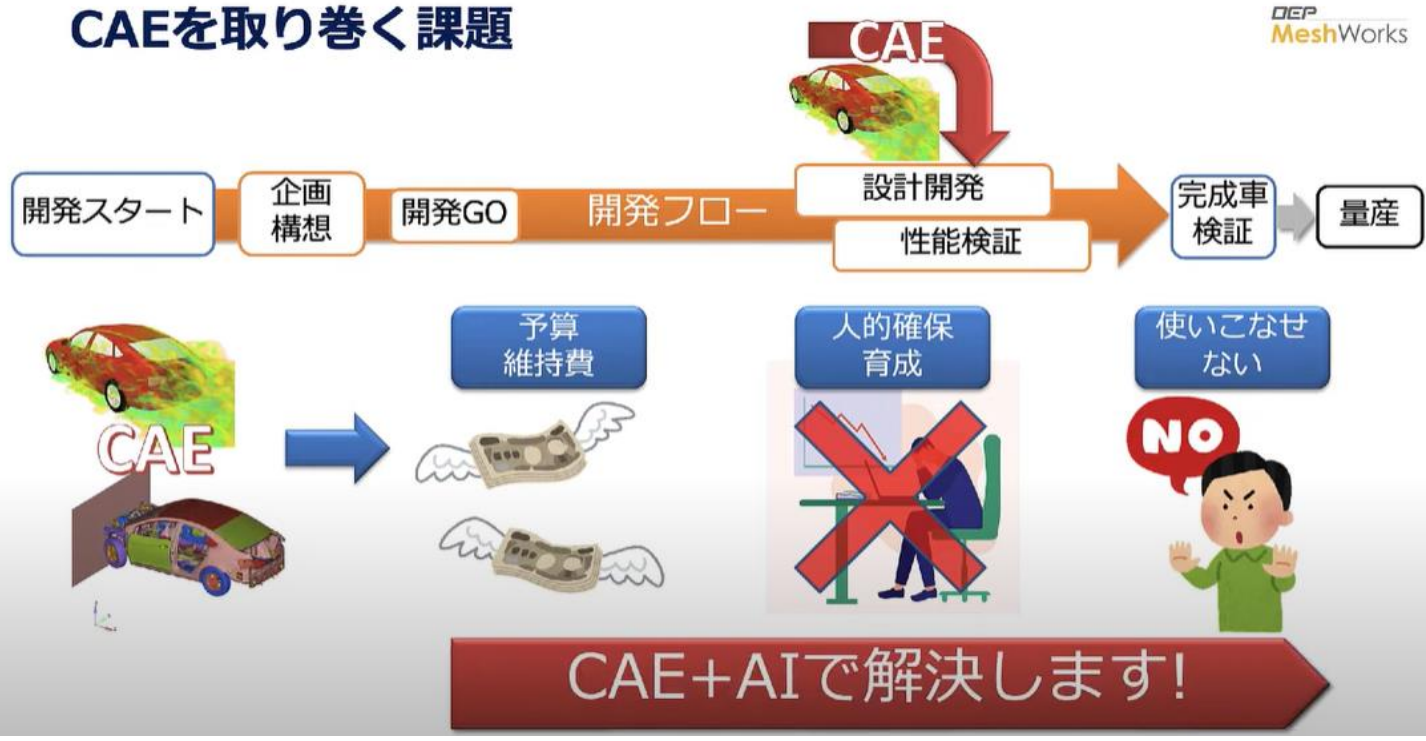
人的確保
育成

人材

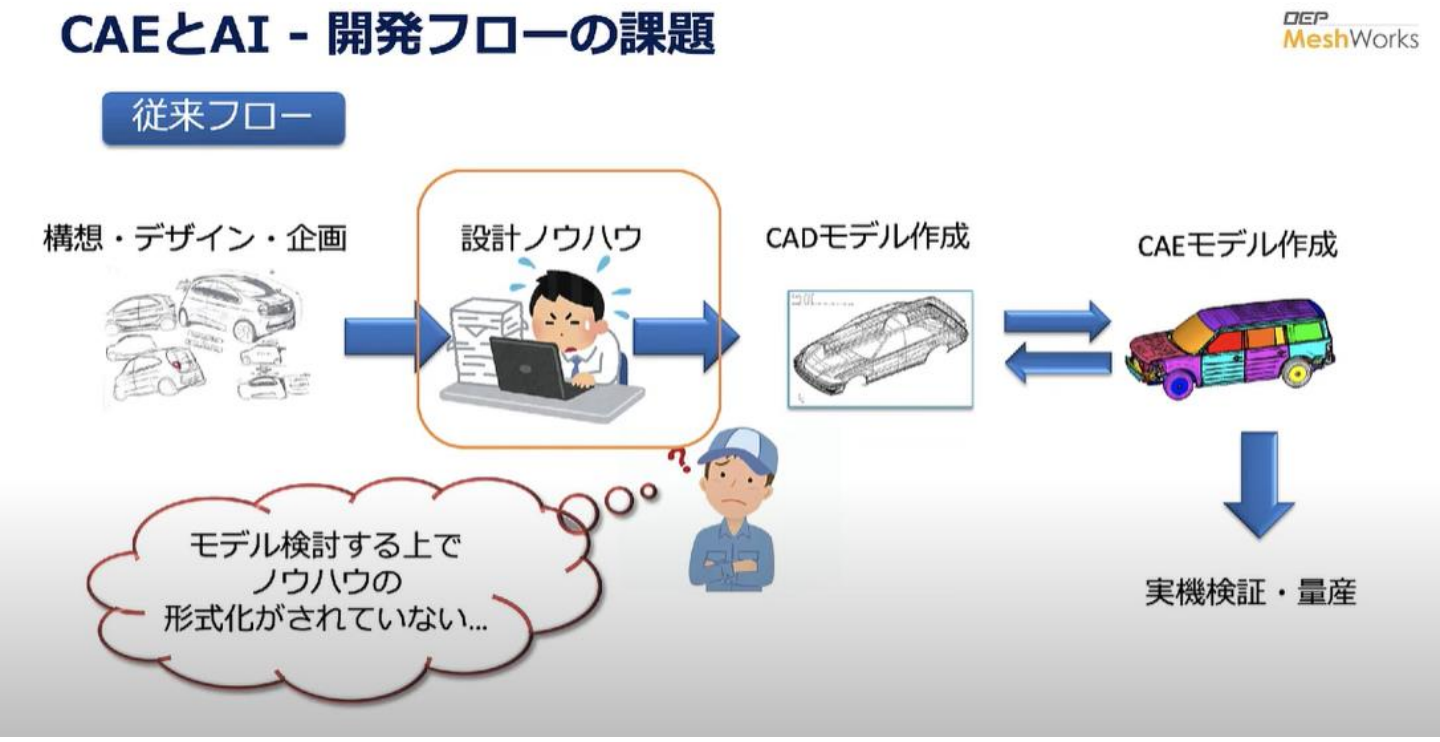
使いこなせない

ツール
定着

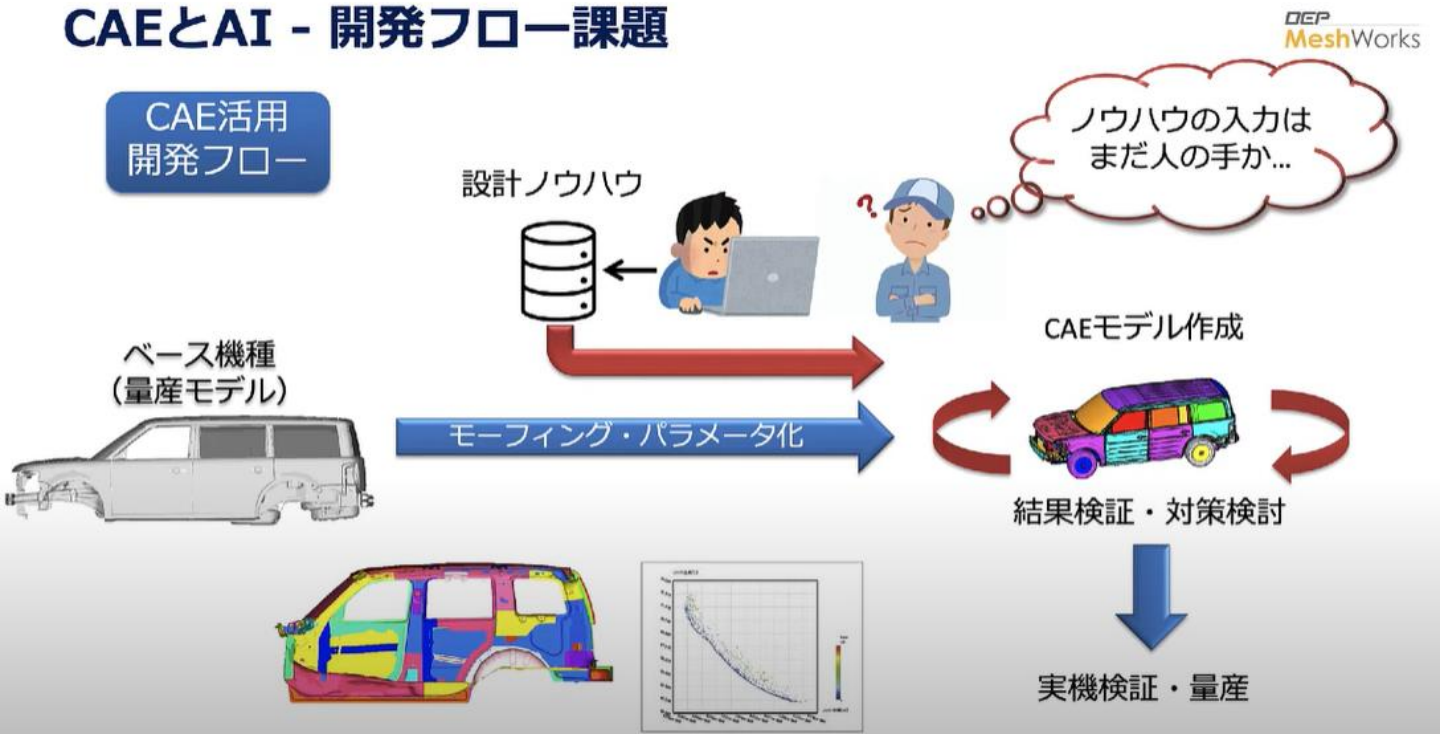
CAEを取り巻く課題



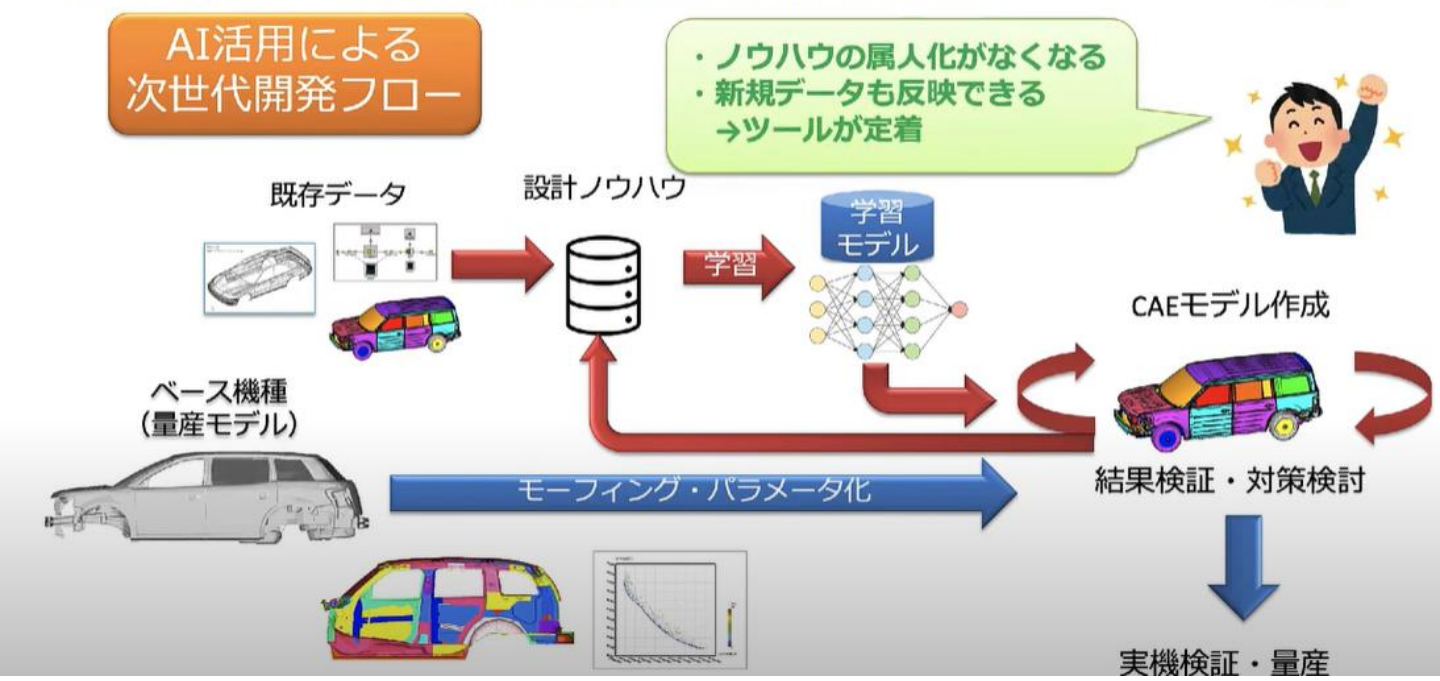
CAEとAI - 開発フローの課題



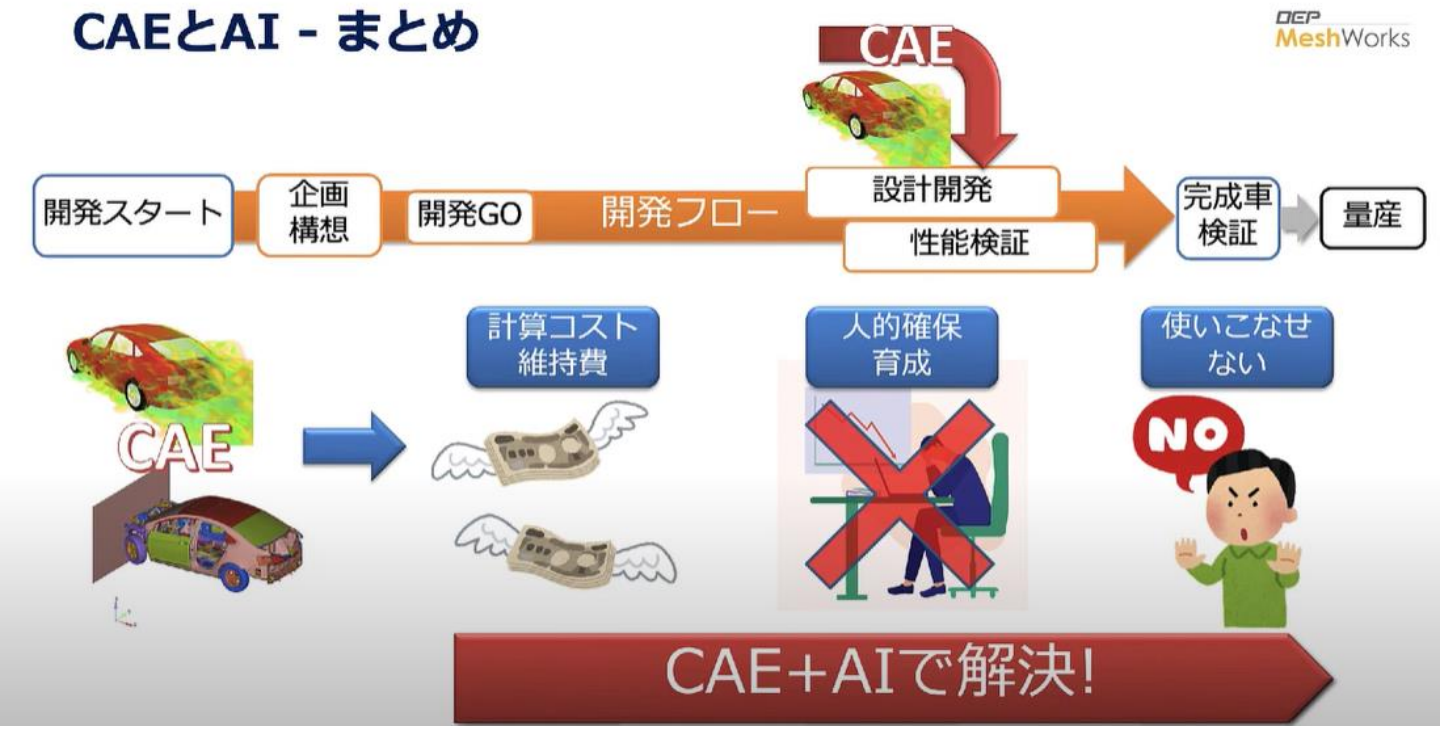
CAEとAI - 開発フロー課題



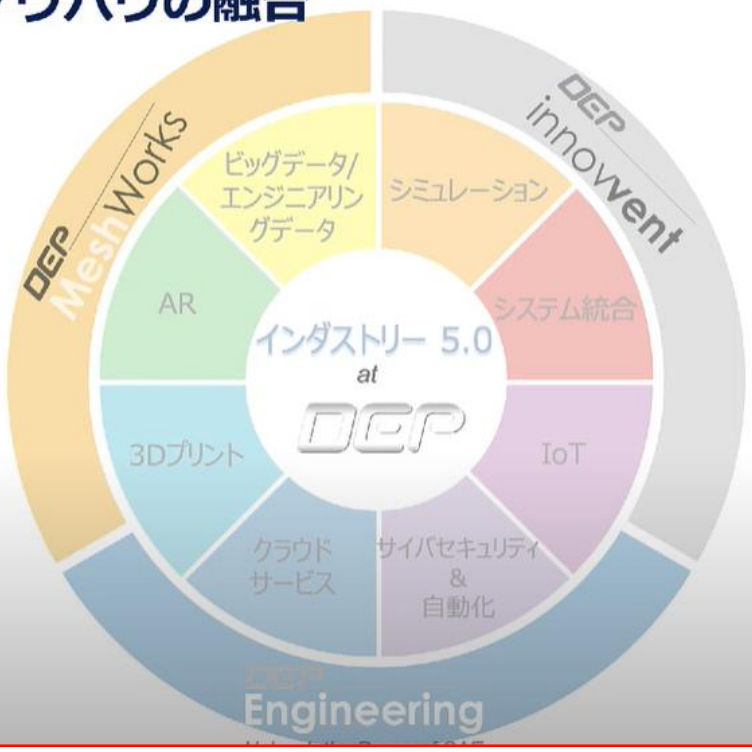
CAEとAI – AI活用による次世代開発フロー



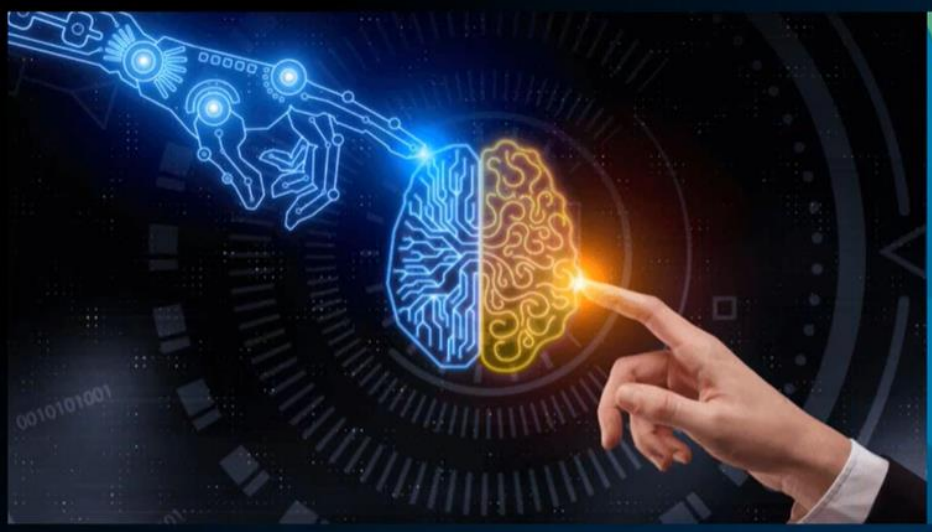
CAEとAI - まとめ



CAEとAI - ノウハウの融合



CAEとAI - ノウハウの融合



Whitepaper: The Emergence of Artificial Intelligence in CAE Simulation for manufacturers

https://www.mscsoftware.com/artificial-intelligence-manufacturing-report?utm_campaign=wcp_cadlm-ai_ww-all_2020-11-18_global-ai-cae-2020&utm_medium=social&utm_source=linkedin&utm_term=cadlm_ai&utm_content=WP

Hexagon
https://hexagon.com › products › odyssee

ODYSSEE

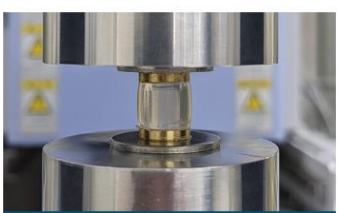
ODYSSEE CAE is an innovative platform for engineers that integrates machine learning, artificial intelligence, reduced order modelling, and design optimisation ...

Case studies

Oil & Gas

Optimisation of casing buckling and deformation responses in shale gas wells

ODYSSEE CAE reduces chance of failure in shale gas wells.



Materials

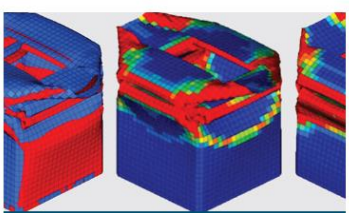
How to optimise the design of vibration insulators using ML-ROM

In this study, Taica engineers focused on the axisymmetric compression type αGEL isolators...

Automotive

Smart motor design with ODYSSEE CAE

ODYSSEE CAE reduces modeling time by 87%.



Automotive

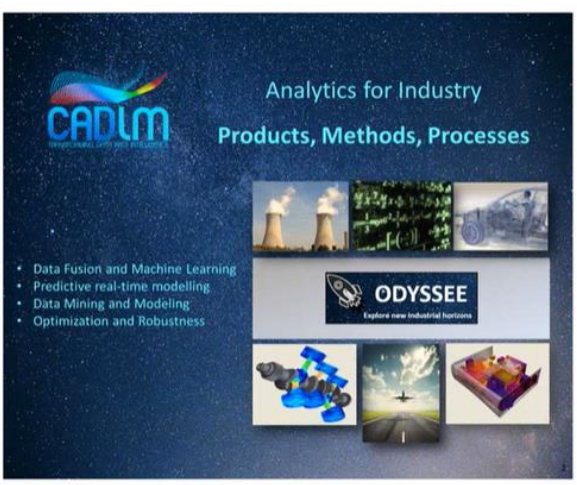
AI/ML based prediction of crash parameters using ODYSSEE CAE

Satven reduces the time required for predicting effects of materials and thicknesses on crash...

AI / ML / ROM for COST reduction

ODYSSEE
Explore new industrial horizons

- Computing (**HW/SW**, CPU, Energy, ...)
- Optimization (**Iterations**, **curse of dimensionality,** precision of surrogate models,, parametric studies, stochastics)
- Simulation (**Model size and complexity**, Multi-physics, multi-scale, encapsulation, model transfer without loss of confidentiality)
- Time (**Real-time**, pre/post automation, animations, etc.)



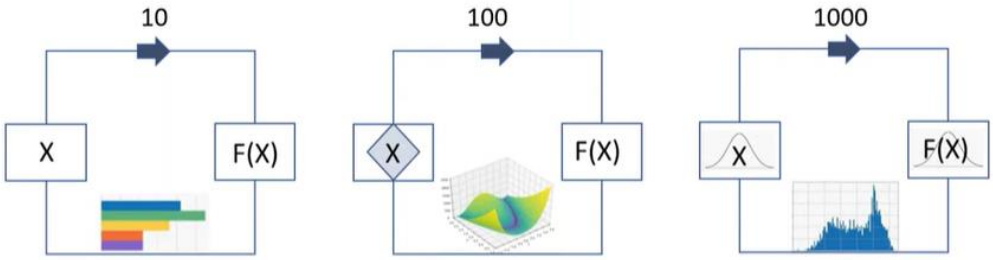
Our Applications

1. Real-Time predictive modeling and optimization (CAE or test data)
2. Image and Sound compression, identification, learning, prediction
3. Fault prediction (Sensor data)

CADLM HEXAGON

Why?

ODYSSEE
Explore new industrial horizons

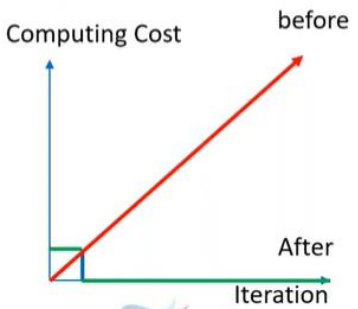


- Parametric Studies
- Trial and error

- Optimization
- Model Fitting

- Reliability Studies
- Robustness

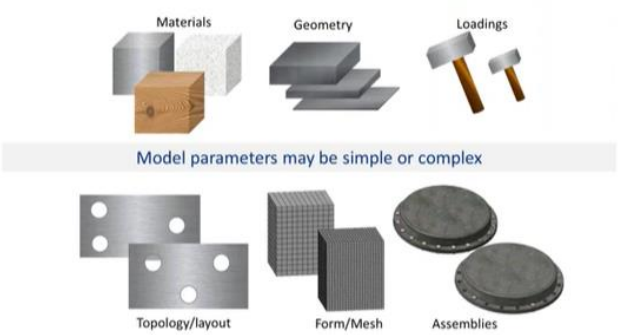
All require numerous solver runs



CADLM HEXAGON

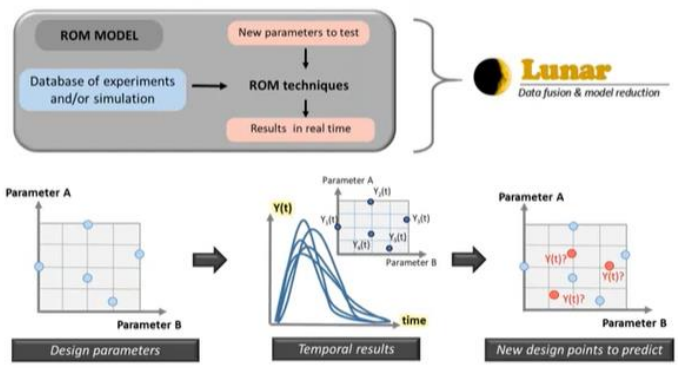
When?

ODYSSEE
Explore new industrial horizons



Multiple Design Parameters

Model Order Reduction (ROM) + ML

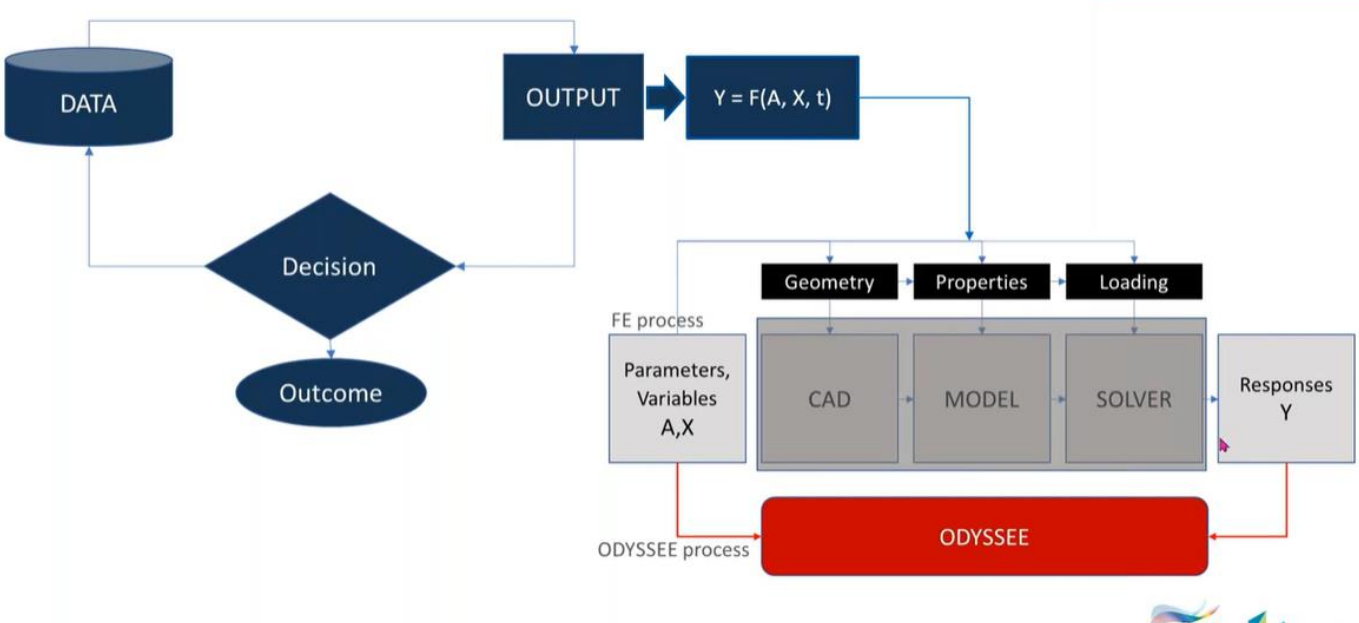


Multiple responses are available

CADLM HEXAGON

How?

ODYSSEE
Explore new industrial horizons



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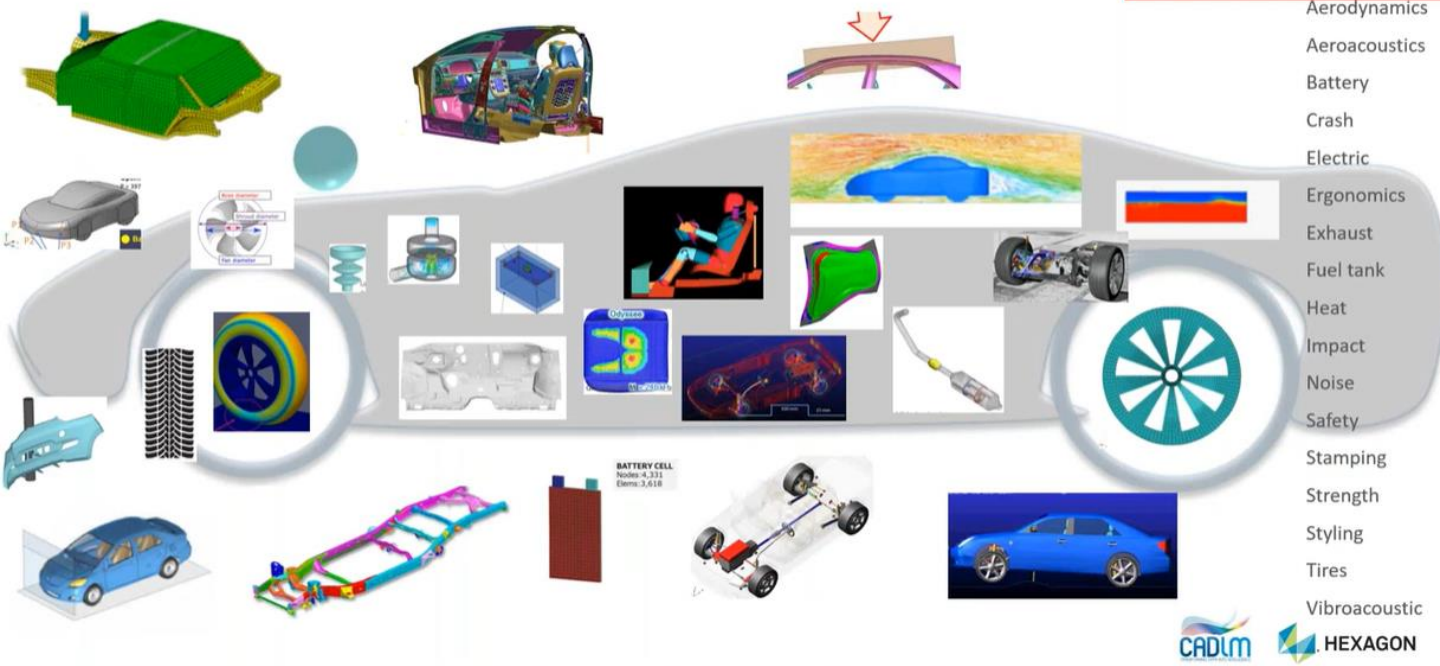
ML/ROM based design & optimization

ODYSSEE
Explore new industrial horizons



- Aerodynamics
- Aeroacoustics
- Battery
- Crash
- Electric
- Ergonomics
- Exhaust
- Fuel tank
- Heat
- Impact
- Noise
- Safety
- Stamping
- Strength
- Styling
- Tires
- Vibroacoustic

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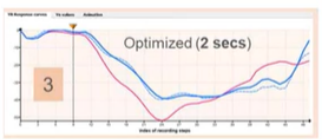
Customer Value proposition

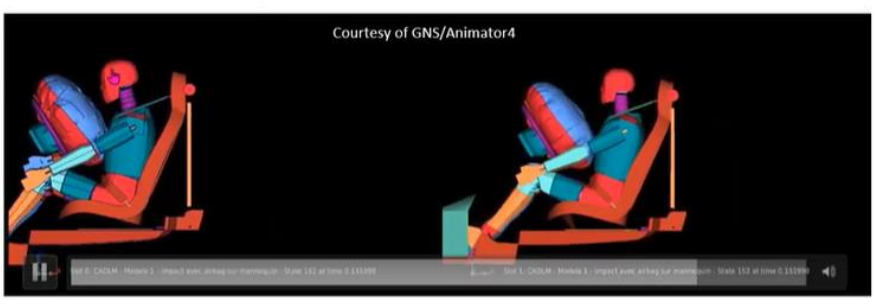
Challenge	Solution	Value
	ODYSSEE Explore new industrial horizons	
COST • CPU -> Energy • Optimality -> iterations • Simulation -> Feasibility • Time -> Time to market	Exploit data : CAE or Tests Learning from Data via • Decomposition • Transforms • Clustering • Neural Networks • Support Vector Machines • …	• Reduced Cost (Energy) • Real Time • Precision • On board

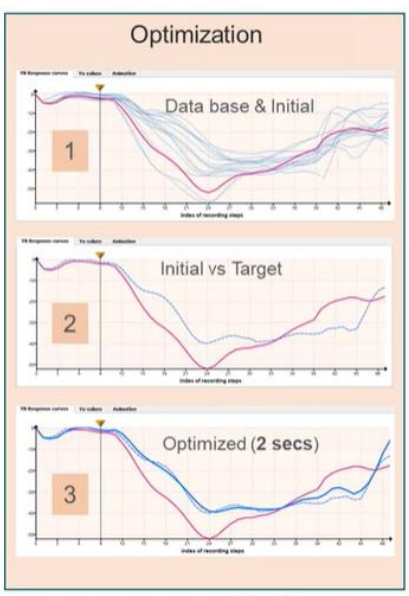
CADLM HEXAGON

ner Value proposition >

SLED TEST + AIRBAG (Optimization)

ODYSSEE
Explore new industrial horizons





15 runs, 3 parameters

Deceleration (breaking speed) => X1, X2

Airbag mass debit => X3

Output Channel

Thorax compression => Y1

Pelvis acceleration => Y2

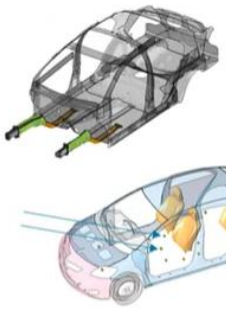
CADLM HEXAGON

Front crash

ODYSSEE
Explore new industrial horizons

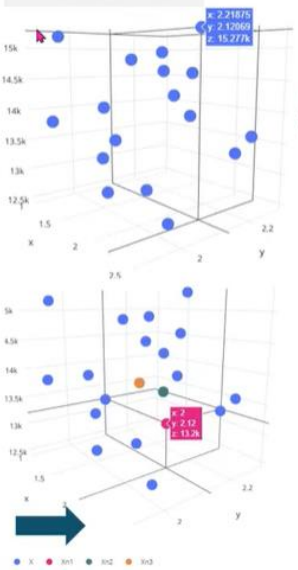
3 Model parameters:
Rail inner thickness => X1
Floor support thickness => X2
Velocity => X3

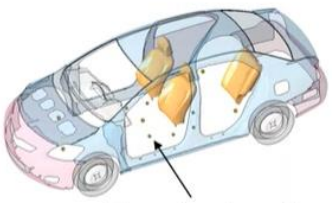
Output channels:
Driver seat acceleration=> Y1
Rigid wall Force => Y2
Gravity center acceleration => Y3



Finite Elements	Lunar
3h per simulation	2 seconds

DOE of 17 runs





Driver seat accelerometer

393329 Nodes
378470 Elements

	Rail inner thickness (mm)	Floor support thickness (mm)	Velocity (mm/s)
Validation 1	2,00	2,12	13200,00
Validation 2	1,60	2,20	13500,00
Validation 3	1,70	2,10	13800,00

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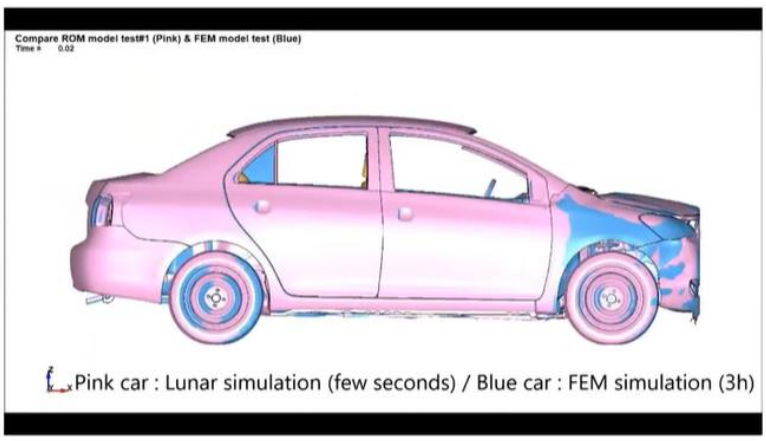
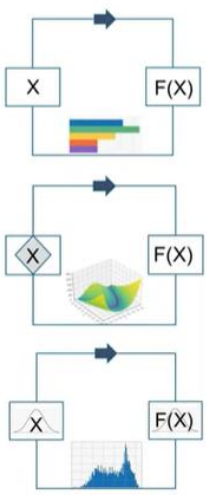
Front crash

ODYSSEE
Explore new industrial horizons

Driver seat acceleration





Lunar: 1 s FEM : 3h

CADLM HEXAGON

Battery short circuit analysis

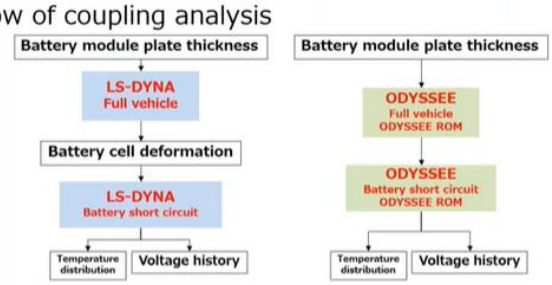
ODYSSEE
Explore new industrial horizons

Multi-scale & multi-physics analysis by ROM

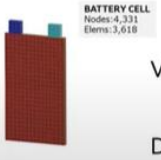
- Require considering two phenomena with different spatial scales
- Multiphysics analysis by structure, Thermal and electromagnetic field

	Full vehicle crash	Battery short circuit	
Solver	explicit	Explicit (structure)	Implicit (Thermal + EV)
DT(sec.)	1.0E-6	9.0E-6	1.0E-3
Phenomenon time (sec.)	0.4		0.1
Num. of step	399,681	11,112	100
COST	2h7m@128core		5min@4core

Flow of coupling analysis



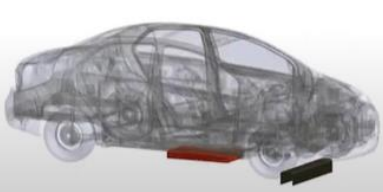
Model specifications



Variables
- IN : Module plate thickness
- OUT : Battery cell deformation

Datasets
- Thickness 0.4 - 2.0 mm, 5 sampling

Costs
- Learning : 0.3 sec
- Predict : 0.4 sec



Courtesy of JSOL Corporation

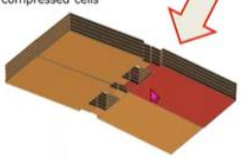
CADLM HEXAGON

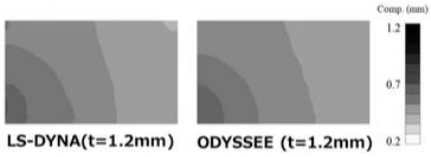
Battery short circuit analysis (Image)

ODYSSEE
Explore new industrial horizons

Solver	Location (Node ID)	Compression (mm)
LS-DYNA	43800015	0.88
ODYSSEE	43800015	0.86 (2.1%)

Predict the compression distribution of the most compressed cells





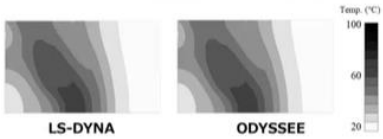
LS-DYNA(t=1.2mm) ODYSSEE (t=1.2mm)

Variables
- IN : Battery cell deformation (Picture)
- OUT : Temperature distribution

Datasets
- 15 sampling

Costs
- Learning : 96 sec
- Predict : 0.3 sec

Solver	Location (Node ID)	Max. Temperature (°C)
LS-DYNA	43800104	89.3
ODYSSEE	43800104	89.1 (0.2%)



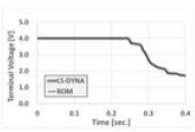
LS-DYNA ODYSSEE

Variables
- IN : Battery cell deformation (Picture)
- OUT : Terminal voltage

Datasets
- 15 sampling

Costs
- Learning : 96 sec
- Predict : 0.3 sec

Solver	Terminal voltage (V)
LS-DYNA	1.71
ODYSSEE	1.72 (0.1%)



- It is possible to dramatically reduce the simulation COST by using ODYSSEE ROM.
- Coupling between different solvers becomes easy by focusing on input / output only.

Solver	Full vehicle Analysis (Structure)		Battery short circuit (Structure+Thermal+EM)	
	COST (sec/core)	Error (%)	COST (sec/core)	Error (%)
ODYSSEE (Learning)	0.3	2.1	96	0.2
ODYSSEE (Predict)	0.4		0.3	
FEM	975,360	-	1200	-

Courtesy of JSOL Corporation

CADLM HEXAGON

Cradle : Front bumper shape optimization

ODYSSEE
Explore new industrial horizons

Physical problem :

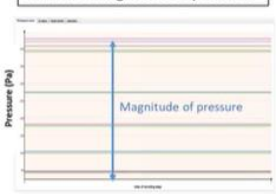
Reduce Pressure at point P2 and we take into consideration a lift coefficient

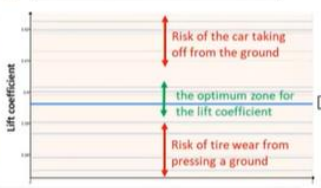
Optimization problem :

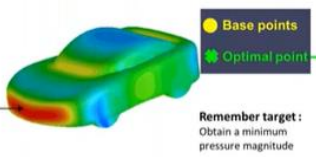
Objective function
Minimize magnitude of pressure

Constraint
Limit the lift coefficient to 0.396

For maximum Flow Velocity =30m/s

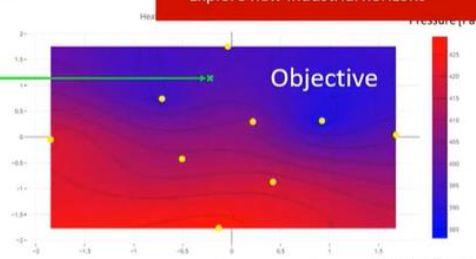


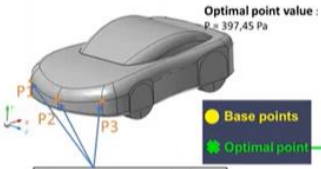




Remember target : Obtain a minimum pressure magnitude

Optimal point value : P = 397,45 Pa

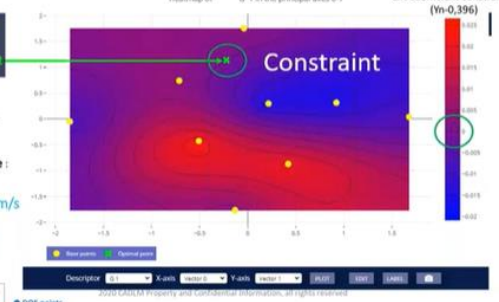




Parameters to optimize
X_Disp , Y_Disp

Remember target : Converge to the 0

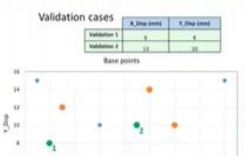
Optimal point value : G1=-6.62E-10



4 Points added to DOE for Velocity=30m/s

New Database

Validation cases

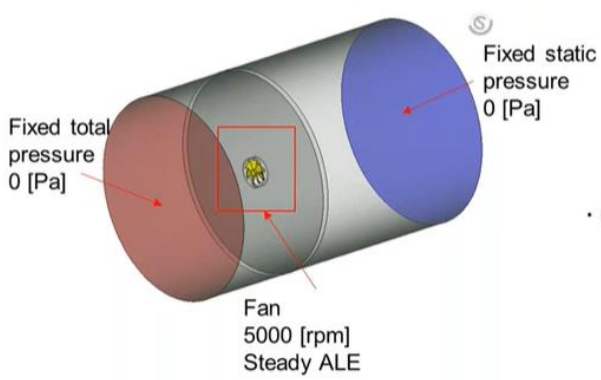


CADLM HEXAGON

scFLOW – Steady-State analysis

ODYSSEE
Explore new industrial horizons

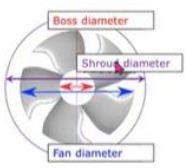
- Prediction of flow rate by fan shape



- Prediction of flow rate by fan shape
  - Design Variables and Objective Function

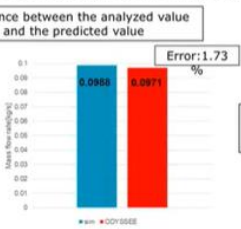
Design Variable	Unit	Min	Max
Number of wings	Sheet	3	10
Shroud diameter	Mm	100	130
Fan diameter	mm	100	120
Boss diameter	mm	30	40

Objective function	Unit
Outlet mass flow rate	kg/s



  - Sampling : Optimal Latin Hyper Cube n=30
  - Comparing scFLOW and Lunar in some design variable combinations.
- Result
  - Comparing scFLOW and Lunar in some design variable combinations.

Difference between the analyzed value and the predicted value



Calculation time
scFLOW :~16min (72Core)
ODYSSEE :Few seconds

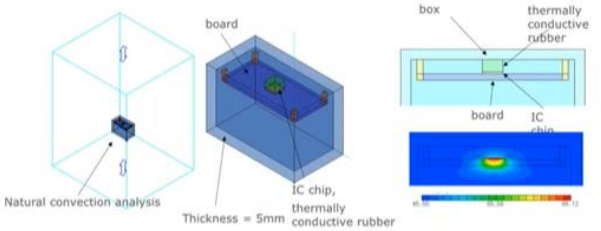
Courtesy of Tomoyuki Hirabayashi (MSC Japan)

CADLM HEXAGON

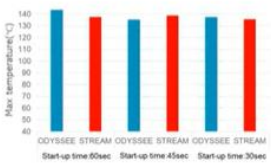
scSTREAM – Transient Analysis

ODYSSEE
Explore new industrial horizons

- Prediction under unsteady heating conditions
  - Predicts the maximum temperature of the IC chip



- Result
  - Max temperature and calculation time



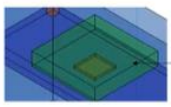
Match in the range of ±6°

Calculation time
scSTREAM :58 sec
(72Core)
ODYSSEE : Few seconds

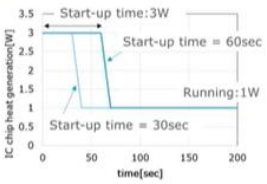
- Prediction under unsteady heating conditions

Design Variable	Unit	Min	Max
Rubber size	mm	10	30
Rubber thermal conductivity	W/(m・K)	0.8	7.3
IC Chip High heat generation Start-up time	sec	30	60

- Objective function: IC chip maximum temperature[℃]
- Sampling : Optimal Latin Hyper Cube n=20



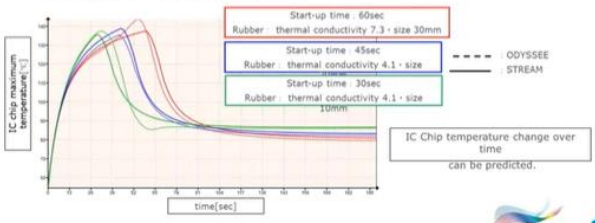
Change the size and thermal conductivity of the rubber



scSTREAM Transient analysis

Reduce heat generation by shortening the start-up time.

- Result
  - Predicting the maximum temperature of an IC chip



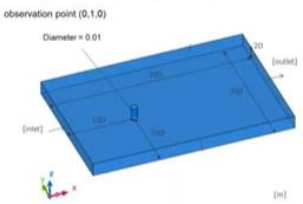
IC Chip temperature change over time can be predicted.

CADLM HEXAGON

scFLOW - Prediction of aerodynamic sound analysis

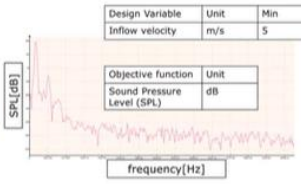
ODYSSEE
Explore new industrial horizons

- Evaluation of aerodynamic sound around a three-dimensional cylinder
  - It predicts the aerodynamic sound when the inflow velocity is changed.



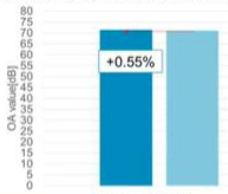
Design Variable	Unit	Min	Max
Inflow velocity	m/s	5	15

Objective function	Unit
Sound Pressure Level (SPL)	dB



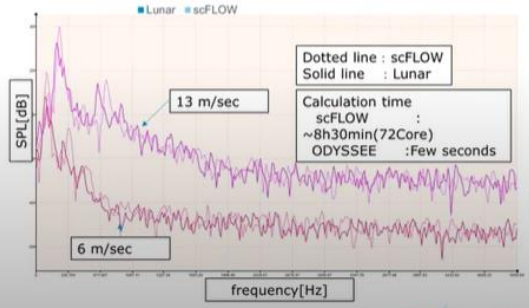
Initial turbulent flow field(LES) Courant Number 5.0 ~3h50min @72Core → Aerodynamic sound analysis(LES) Δt = 2μs ~4h40min @72Core → POST SPL analysis ~1min/data → Lunar Prediction Few seconds

- Result : OA value
  - Comparison of scFLOW and ODYSSEE , with training in OA value(overall value, Total sound pressure)
  - 13m/sec conditions were evaluated.
  - The predicted deviation of OA values was less than 1%, which was highly accurate.



Succeeded in predicting OA values with an accuracy of approximately 99.5%.

Over 3,000 times faster with over 99% prediction accuracy



Courtesy of Tomoyuki Hirabayashi (MSC Japan)

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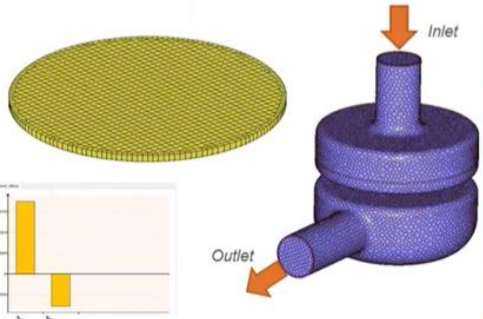
Pump optimization with multi-physics interaction

ODYSSEE
Explore new industrial horizons

Design of experiments

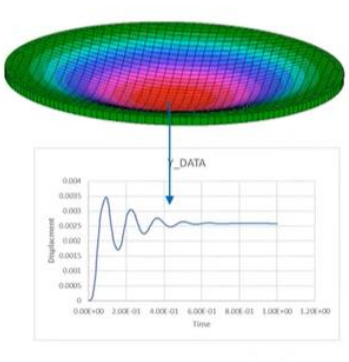
X: (2 variables)

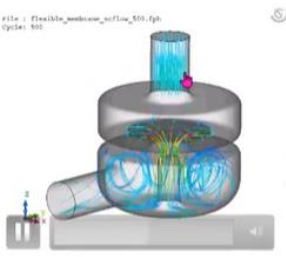
1. Inlet Fluid Speed
2. Membrane Stiffness



Y:

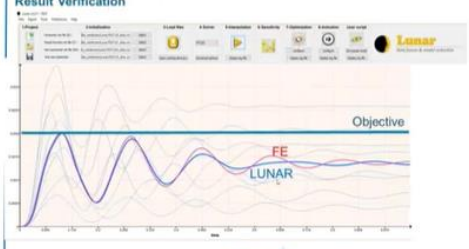
1. Displacement center of membrane





x 8

Result Verification



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Courtesy of Fabio Scannavino – MSC Italy

Simulation Driven Design

Product Requirements & Objectives

Questions

Product Definition

Reports & Results

Can I build it?

Is it durable?

Will it fail?

Is it safe?

Can I test it?

Will it perform?

Is it crashworthy?

Why did it fail?

Can it be lighter?

Is it too loud?

Optimized Designs

Simulation + Tests

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Simulation Driven Design

Product Requirements & Objectives

Questions

Product Definition

But...

- Takes too long
- Not all data is available
- 95% deemed to be unevaluatable data
- Too expensive
- Difficult engineering judgement with increasing number of disciplines
- Limited Predictive adaptive models integrating future complexity

Reports & Results

Optimized Designs

Simulation + Tests

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Simulation Needs to Evolve

Today

- Takes too long
- Not all data is available
- 95% of unevaluable data
- Too expensive
- Difficult engineering judgement with increasing disciplines
- Limited Predictive adaptive models integrating future complexity

Leading to …

- Unexplored New designs
- Unexplored new variants
- Limited innovation
- Reduced quality
- Not fully connected digital and real worlds

CAE faces new challenges

- Frontloading Simulation
- Democratization of CAE
- Increasing simulation Throughput
- Multidisciplinary
- Real-Time Optimization
- Materials
- Manufacturing effects & 3D printing
- Autonomous Connected Ecosystems (ACE)

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Machine Learning (ML) Process

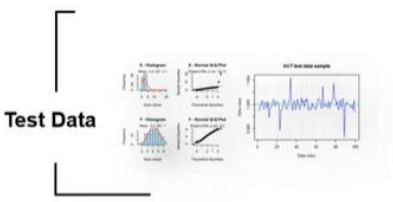
Phase 1 : Learning

Phase 2 : Prediction

ML is used when:

- People are unable to express their expertise
- Answers have to be provided in Real-time

Data is the fuel for Machine Learning : Simulation is the cheapest



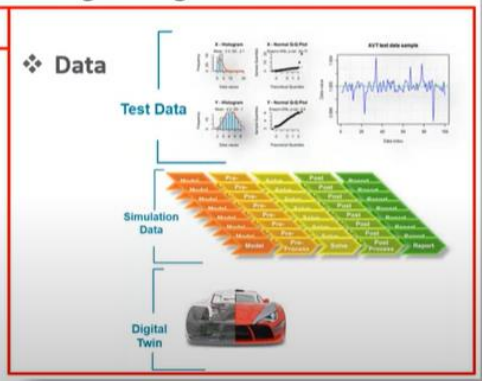
Simulation Data	Test Data	Digital Twin
• Design the feature set • Always generate more training data • DOE • The simulation output data is detailed, precise and complete. • Control the statistical distribution of the data	• Real-world data	• Real-world data • Essential for Life-cycle history

Simulation Data	Test Data	Digital Twin
• "What if" loops take too long vs. current time-to-Market competitive pace • HPC is not affordable everywhere (Cloud as an alternative)	• "What if" loops take too long • Way too expensive • Incomplete data	• Too late for predictive maintenance • A posteriori data

Only with Simulation can sufficient and meaningful data be realistically and cost effectively generated to make AI successful in engineering

Machine Learning applied to simulation

Today	What ML can offer	Prerequisites
❖ Takes too long	❖ Answers in seconds	❖ Engineering Dedicated AI tools
❖ Not all data is available		
❖ 95% of unevaluable data	❖ All available data is Value	❖ Data
❖ Too expensive	❖ Easy to handle	
❖ Difficult to make engineering judgement with increasing number of disciplines	❖ Limited compute power ❖ Consistent Engineering Judgment	
❖ Limited Predictive adaptive models integrating future complexity	❖ Fusion technics combining R.O.M. and ML are game changers !	



R.O.M. = Reduced Order Model

More Valuable Simulation – More Innovation

Requires real-time solver runs
Digital Twins

Design

Manufacturing

Service

Real-Time

Cost Effective Simulation

Productivity & cost Value

More Valuable Simulation

Room for increased innovation

ing Simulation Value >

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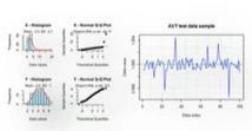
AI based Simulation

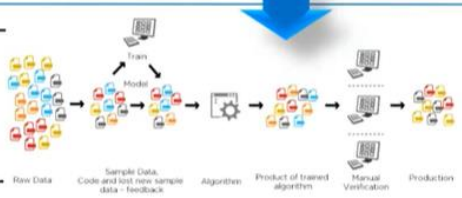
Simulation Data

Test Data



Digital Twin

AI Model



Model | Pre-Process | Solve | Post Process | Report

Data segregation | RT solve

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AI applied to a given design space

Industry Pain Points

- A need for increasing engineering insight within **shorter design cycles**
- How to **leverage 90%+ data** gathered over time not being used while containing precious knowledge and insight
- How to **understand Product design response instantaneously** to design variations or uncertainties in time scales aligned with increasing market demand
- How to **complement FE/FV solution** by increasing efficiency and capacity of fast (real-time) parametric studies

Why Hexagon MI & CADLM

- Reduced Order Modelling (ROM) for **Real-time Predictive parameter studies and optimization**
- Reduced computing effort (small samples), apply **adaptive learning** to design space
- Gain precision and completeness via **parametric time-histories**
- Benefit from **real-time visualization** (no need to wait for lengthy FE/FV runs)
- Released Technology available now as a product !

Case Studies

Knowledgeable and re-usable AI model

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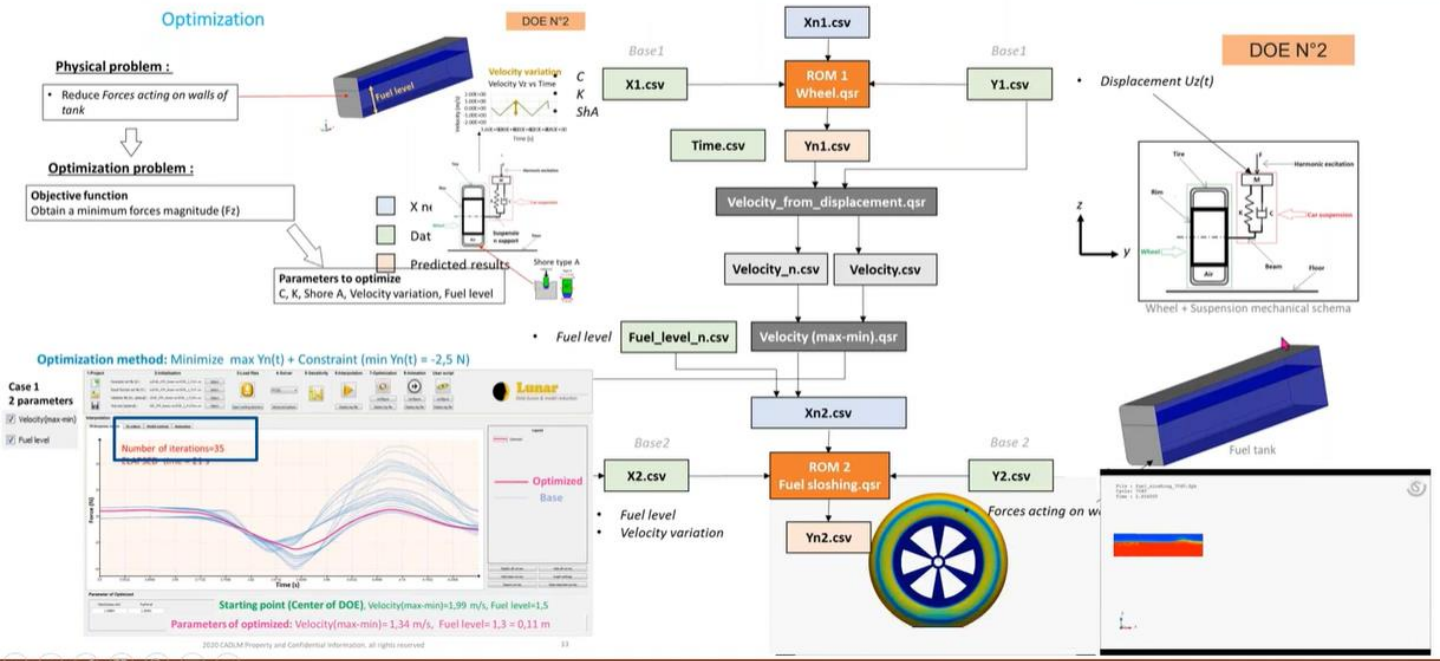
Coupled Tire / Fuel Tank optimization

ODYSSEE
Explore new industrial horizons



Wheel impact on pavement
Learning from images and sensors : Y(t)

ODYSSEE
Explore new industrial horizons

X_parameters

	Initial Velocity	Number of branches
M1	9	9
M2	4	9
M3	9	10
M4	8	8
M5	7	10
M6	6	9
M7	10	6
M8	10	7
M9	8	7
M10	5	8
M11	6	6
M12	7	5
M13	5	5
M14	3	8
M15	4	7
M16	3	6
M17	3	5
M18	3	10
M19	10	5
M20	10	10
M21	7	7
M22	10	9


5_Branches_APEX.PNG


6_Branches_APEX.PNG

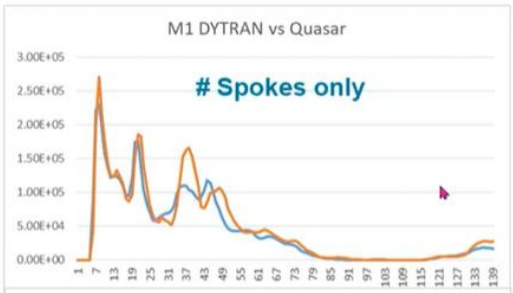
X_image

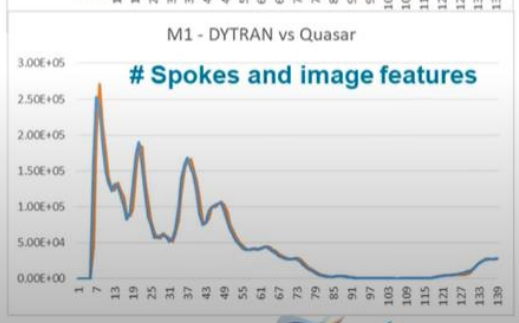

7_Branches_APEX.PNG


8_Branches_APEX.PNG


9_Branches_APEX.PNG


10_Branches_APEX.PNG





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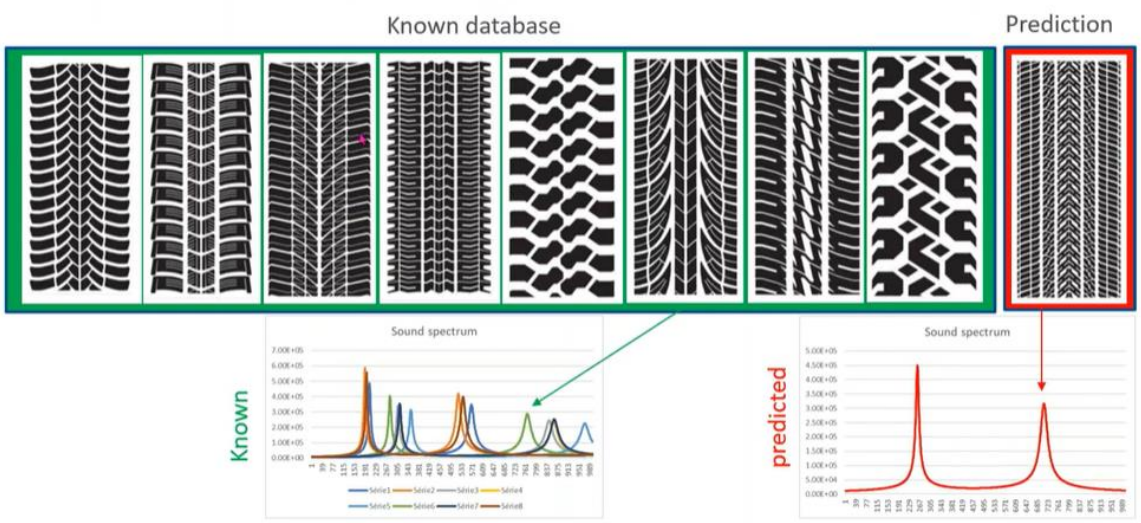
Sound spectrum prediction form images

ODYSSEE
Explore new industrial horizons



CADLM HEXAGON

Our Customers

ODYSSEE
Explore new industrial horizons

arianespace ariane GROUP
THALES
SAFRAN
TOYOTA
BOMBARDIER
HONDA
DAIHATSU
Toyota Motor North America
faurecia inspiring mobility
Ford
PSA GROUPE
TOYOTA Toyota Industries
JFE
TOYOTA
Autoliv
OPEL
Seiko Epson Corporation EPSON
YAMAHA Revs Your Heart
Schlumberger
ULVAC
Kubota
azbil
Nikon
TOYOTA BOSHOKU
AsahiKASEI
nexter
TOYODA GOSEI
TOYOTA
DAIMLER
mazda
Toyoda Iron Works
ArcelorMittal
Technatics GROUP
トヨタ車体 TOYOTA AUTO BODY
INSTITUT VEDECOM

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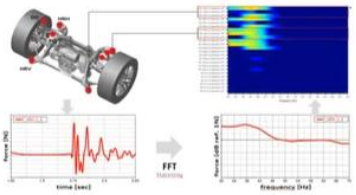
Vibration Optimization

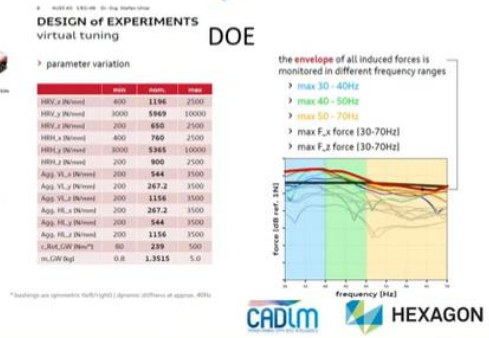
ODYSSEE
Explore new industrial horizons

MODEL

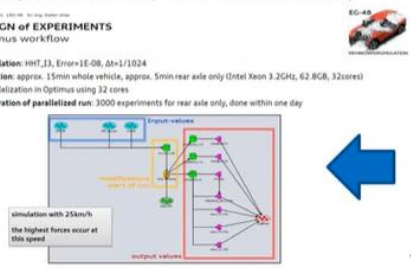


Simulating and Optimizing the Dynamic Chassis Forces of a BEV
MSC Vehicle Dynamics Conference 2019
Dr.-Ing. Stefan Uhler, AUDI AG
12/11/2019

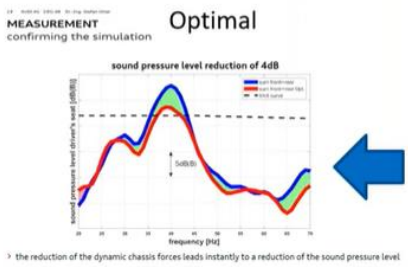
DOE



Optimization (3000 Adams runs)



Optimal



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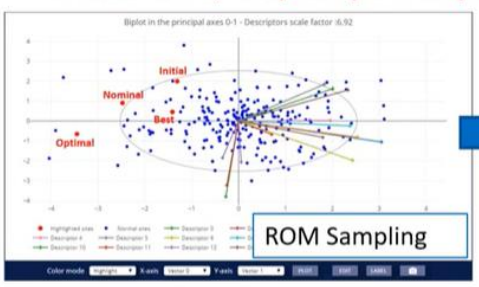
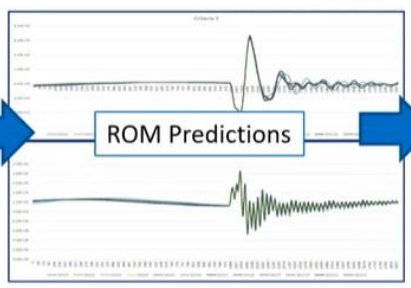
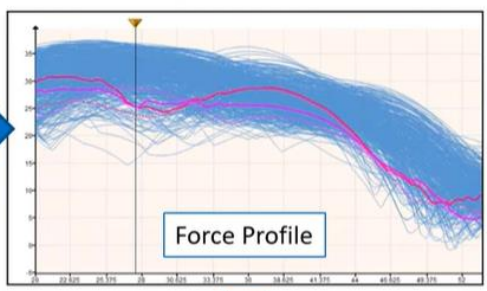
Learning from 240 runs (instead of 3000)

ODYSSEE
Explore new industrial horizons

Minimize Force/Frequency envelope

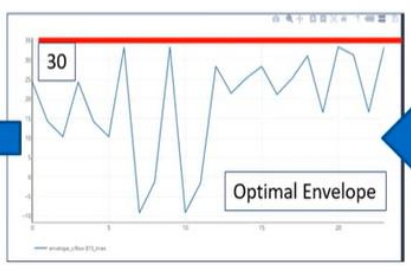






"With ODYSSEE we could significantly reduce the DOE-Runs by a factor of 10 while retaining the quality of results. The always upcoming answer of different mount setups can now be answered within seconds instead of performing new exhausting simulations. We strongly believe in the great potential of ODYSSEE to boost the engineer's comprehension of complex nonlinear mechanical systems."

Dr. Stefan Uhler , Audi

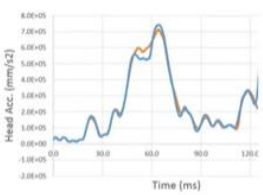


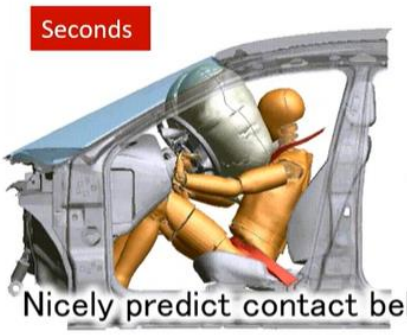
CADLM HEXAGON

Full vehicle Passenger safety (CPU)

ODYSSEE
Explore new industrial horizons

Odyssee **Seconds**

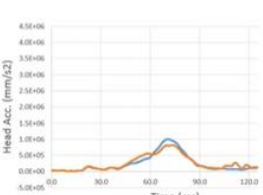


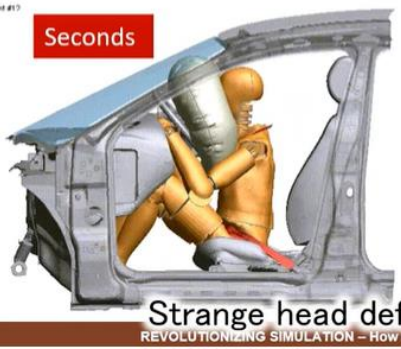


LS-DYNA **Hours x**

Nicely predict contact behavior between airbag and dummy

Odyssee **Seconds**





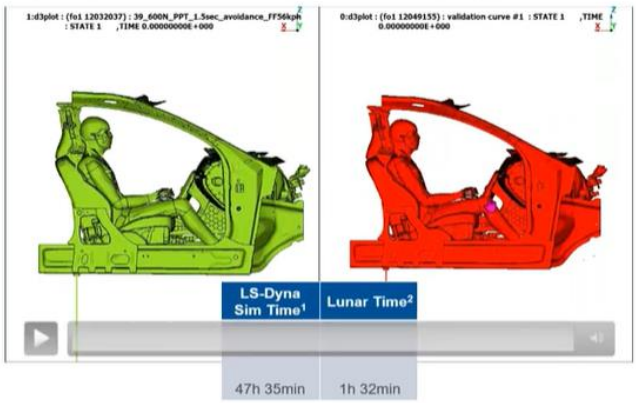
LS-DYNA **Hours**

Courtesy of JSOL

Strange head deformation can be observed

Pre-crash avoidance manoeuvre and crash

ODYSSEE
Explore new industrial horizons



"At AUTOLIV we are concerned with safety of real humans (and not only dummies). This requires a yet challenging computing effort for evaluation of our safety solutions. CADLM's ODYSSEE.Lunar software is a real breakthrough and provides a very promising perspectives in order to reduce drastically computing time and optimize our designs" Bengt Pipkorn (Director Simulation and Active Structures, Autoliv Research)

6 Runs only

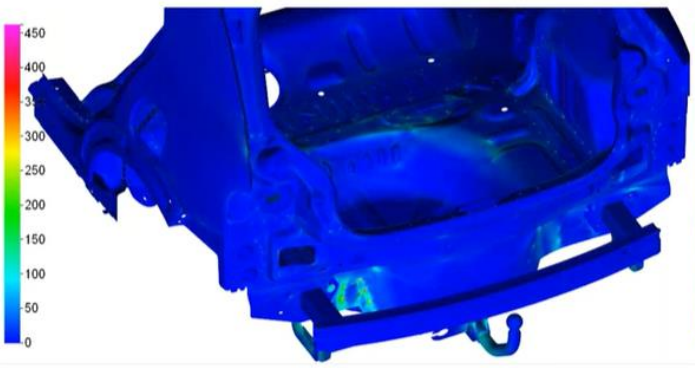
1. Simulation carried out in Autoliv Research Cluster – PBS Nodes – Intel Xeon E5 (32 cores)
2. Calculations on company HP Zbook laptop (Intel Core i7 – 4910MQ – 4 cores)

CADLM HEXAGON

Vibro Acoustic

ODYSSEE
Explore new industrial horizons

PSA GROUPE



$\sigma_{Nastran}$ Courtesy of PSA σ_{Lunar}

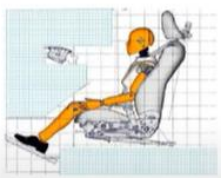
CADLM HEXAGON

Small size female driver investigation

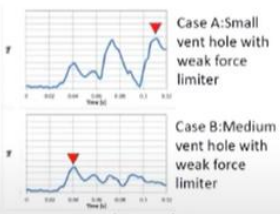
ODYSSEE
Explore new industrial horizons

Background

•Nij of HYBRIDⅢ AF05%ile dummy at passenger seat was studied by sled FE model. Timing of the maximum value of Nij depended on parameter of seat belt and airbag. Response surface method may not be applicable to optimize Nij in this case. ODYSSEE, developed by CADLM company and presented at 10th European LS-DYNA Conference, was applied to estimate time history of Nij.



Sled FE model for NCAP

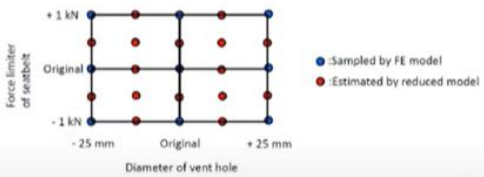


Time history of Nij

Integrated Safety TOYOTA

Case study

•Force limiter of seatbelt and diameter of vent hole were parameters.
•Nine cases were sampled and simulated by FE model for generating reduced model.
•Sixteen cases were reconstructed by the reduce model and validated with results of FE model.



Integrated Safety TOYOTA

TOYOTA

Courtesy of Toyota Motor Company – Tsuyoshi Yasuki, LS-DYNA conference 2016

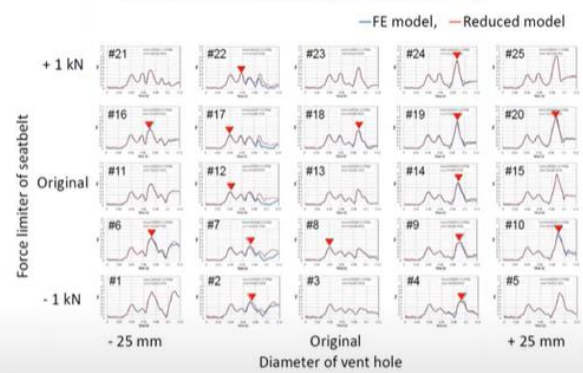
SIMBIO-M--CADLM-REDUCED MODELLING, Kambiz Kayvantash– 18/19.06.2018

CADLM HEXAGON

Small size female driver investigation

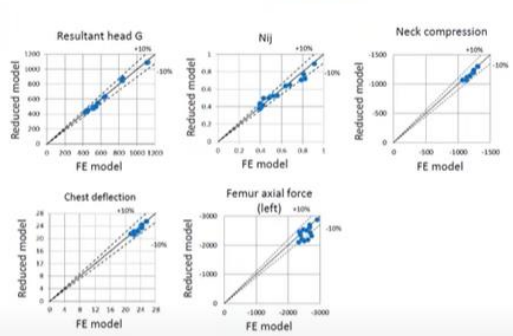
ODYSSEE
Explore new industrial horizons

Validation of Nij (Normarized)



Integrated Safety TOYOTA

Summary of case study for two parameters



Integrated Safety TOYOTA

Courtesy of Toyota Motor Company – Tsuyoshi Yasuki, LS-DYNA conference 2016

Full Crash simulation : 10h on 96 CPU– ODYSSEE Model < 10s on laptop

CADLM HEXAGON
rash >
Rev-sim.org/webinars REVOLUTIONIZING SIMULATION – How to power CAE with AI & ML 2020-2021

Vehicle Aerodynamics

ODYSSEE
Explore new industrial horizons

Development of Reduced Model for Aerodynamic Drag and Lift

Mashio Taniguchi;Junichi Inokuchi;Yasuo, Development of Reduced Model for Aerodynamic Drag and Lift, JSAE Paper Number: 20186092, Oct, 2018 Issued No.121-18

Mashio Taniguchi Junichi Inokuchi Yasuo Yamamae Hiroshi Tanaka Tsuyoshi Yasuki

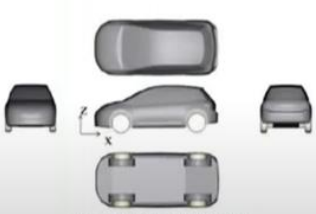


Fig. 2 Vehicle model (Base)

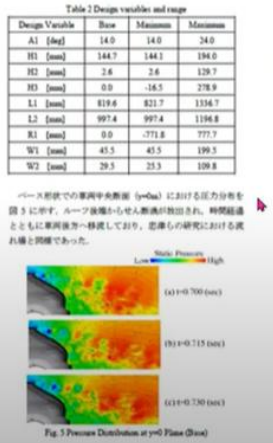


Table 2 Design variables and range

Design Variable	Base	Maximum	Maximum
A1 [deg]	14.0	14.0	24.0
H1 [mm]	144.7	144.1	194.0
H2 [mm]	2.6	2.6	129.7
H3 [mm]	0.0	-16.5	278.9
L1 [mm]	819.6	821.7	1334.7
L2 [mm]	997.4	997.4	1196.8
R1 [mm]	0.0	-771.8	777.7
W1 [mm]	45.5	45.5	199.5
W2 [mm]	29.5	25.3	109.8

Fig. 5 Pressure Distribution at y=0 Plane (Base)

Reduced Model に新たな変数を入力して, C_D, C_L を算出する.

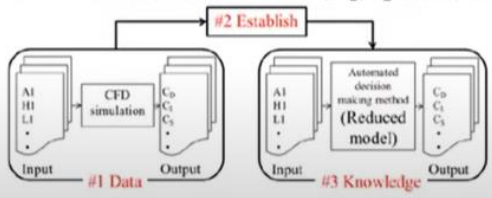


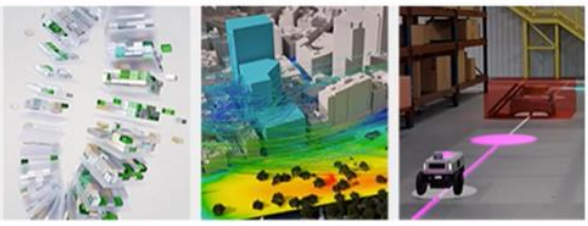
Fig. 1 Automated decision making method

TOYOTA

CADLM HEXAGON

ソフトウェアウェビナーシリーズ

3 つのシミュレーション関連 注目技術をわかりやすく解説



タイトル: Vol. 3

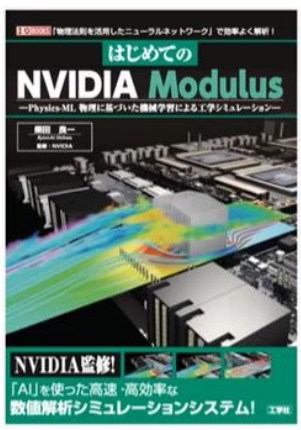
「AI サロゲートモデルでシミュレーションを高速化する方法とは？」

【日　程】 2023 年 7 月 27 日 (木) 14:00 – 15:00 (60 分)　[担当 14:15 – 15:00 (45 分)]
【対　象】 大学や企業で CAE 活用を研究の方、CAE に Physics-ML 導入をご検討の方
【主　催】 エヌビディア 合同会社
【参加費】 無料 / 事前登録制
【配信方法】 ON24 Simulive (Q&A はテキストにてライブでご対応いたします)

独立行政法人 国立高等専門学校機構　岐阜高等専門学校　建築学科　柴田良一

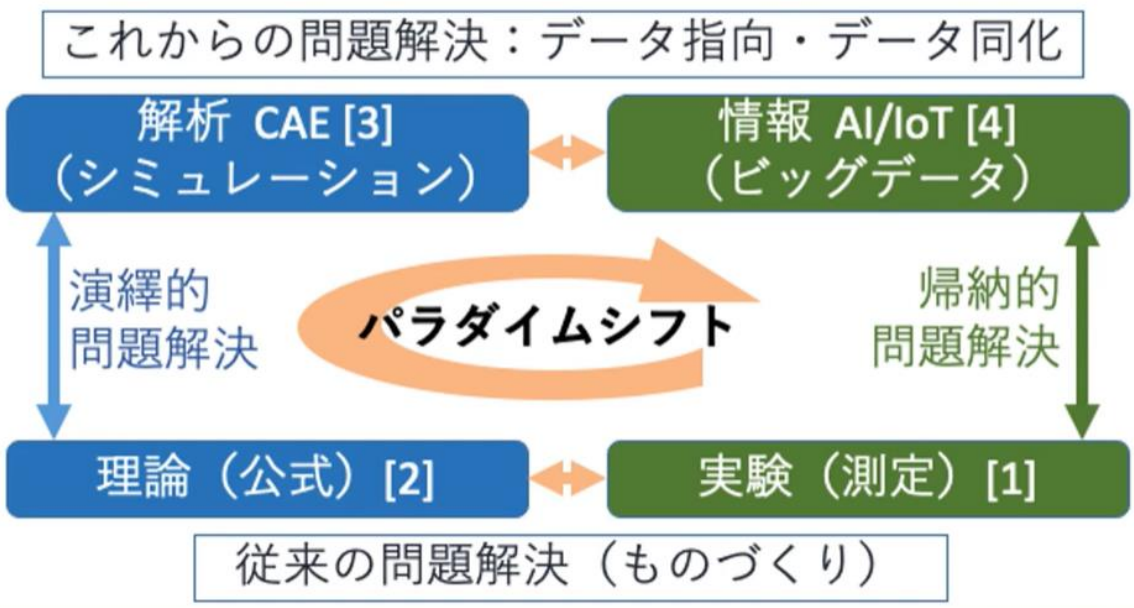
【01】今日のウェビナーの内容

構造解析や数値解析に取り組んできた柴田が、
「**CAE+AI**」の効果的な活用を実現するために、
「**Physics-MLやPINNs**」に注目して、
「**NVIDIA Modulus**」の活用を目指して、
「**最初の第一歩**」を踏み出す情報を説明します。



講演は工学社「**はじめてのNVIDIA Modulus**」の概要となっており詳しくは本書をもとにご活用ください。
・Modulus概要説明（書籍第１章：1-1節・1-２節）
・Modulus構築手順（書籍第１章：1-3節）
・Modulus動作デモ（Moulusの環境・起動・例題）
書籍情報https://www.kohgakusha.co.jp/books/detail/978-4-7775-2262-0

【02】ものづくりにおける問題解決手法



【03】新しい機械学習による問題解決

「課題１：計算規模の拡大化」
数億要素を超える大規模化で著しい計算コスト(経費や時間)の増大が問題

「課題２：設計時間の短縮化」
最適化が必要とされ、繰り返し行う設計検討における解析の効率化が必要

「課題３：解析条件の複雑化」
複数の物理現象による相互作用を検討する場合には連成解析の実現が必要

「目的１：最適化設計：パラメトリックな解析」
１ケースずつ設計評価を行う数値解析を繰返して実行する必要

「目的２：原因分析：逆問題による要因の特定」
期待する目的を満足するために設計変数の値を逆に推定する必要

【04】PINNsでの問題解決への期待と実現

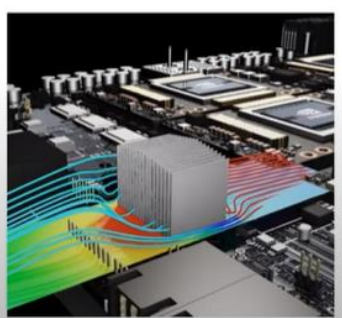
「目的１：最適化設計：パラメトリックな解析」
Modulusを用いることで、
設定変数のパラメータもニューラルネットワークの入力条件に組み込み
最適化設計でパラメータの組み合わせに対応したモデルとして、
効率よく解析結果を得ることができる。

「目的２：原因分析：逆問題による要因の特定」
Modulusを用いることで、
学習を終えたAIモデルから測定結果の要因を導くことが可能になり、
これにより問題を記述する微分方程式の係数を、
逆問題として決定することが可能になります。

【05】NVIDIA Modulusの概要

「NVIDIA Modulusとはなにか」
偏微分形式の支配方程式や境界条件で定義された物理法則の情報を、
ニューラルネットワークの学習用データと統合することで、
高い表現能力を持ちながらパラメータによる問題定義を可能にした、
ニューラルネットワーク用いたサロゲートモデルの構築を可能にするツール。

「活用事例」



ヒートシンクの
最適化設計問題

大規模風力発電の精密な流体挙動分析

【06】NVIDIA Modulusの機能

「順問題としての従来形式のシミュレーション」
有限要素法・有限差分法・有限体積法などのシミュレーションソルバー

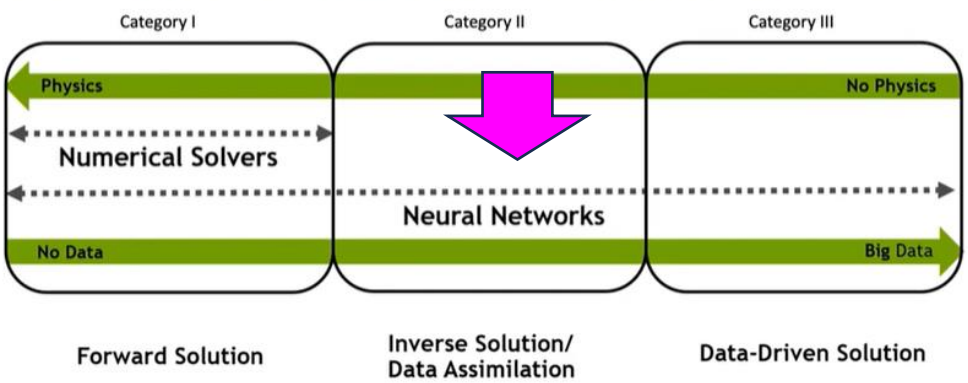
「パラメータ定義による多様なシミュレーション」
問題の条件設定を定数だけではなく変数で記述するパラメータ化を実現する

「逆問題の解決を目的としたシミュレーション」
測定されたデータから、推論される未知の問題構造の特性を推測する

「デジタルツインのリアルタイムシミュレーション」
現実世界のデータとコンピュータ内の仮想空間とを連携したデジタルツイン

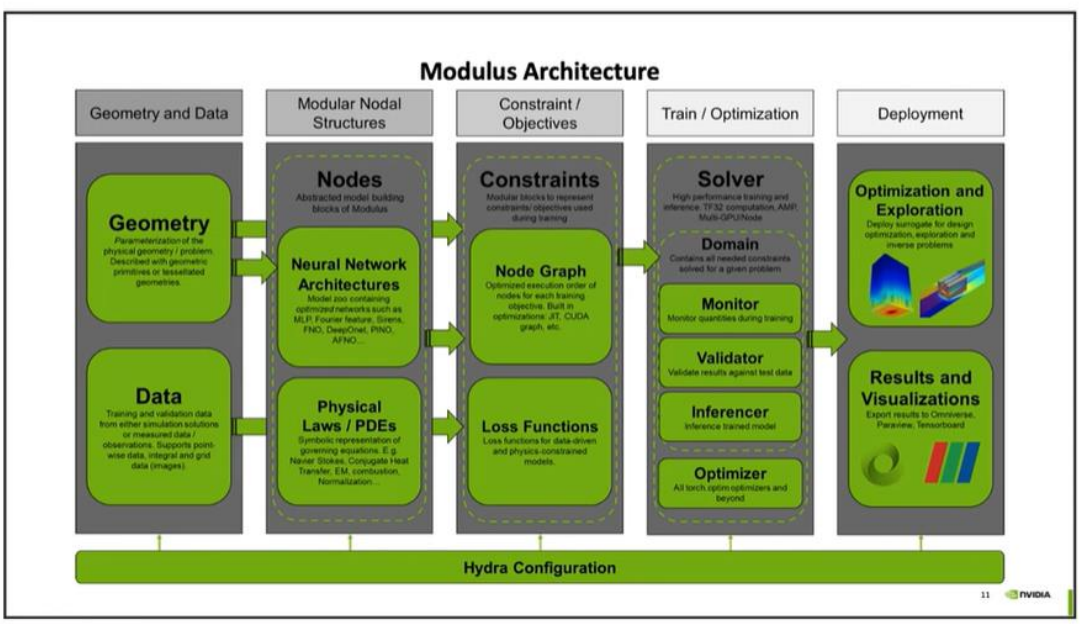
【07】NVIDIA Modulusの特徴

「1：専門技術者向け人工知能ツールキット」
「2：スケーラブルなPINNsの学習性能」
「3：PINNs処理環境の活用や導入が容易」
「4：リアルタイムに近い推論処理実現」



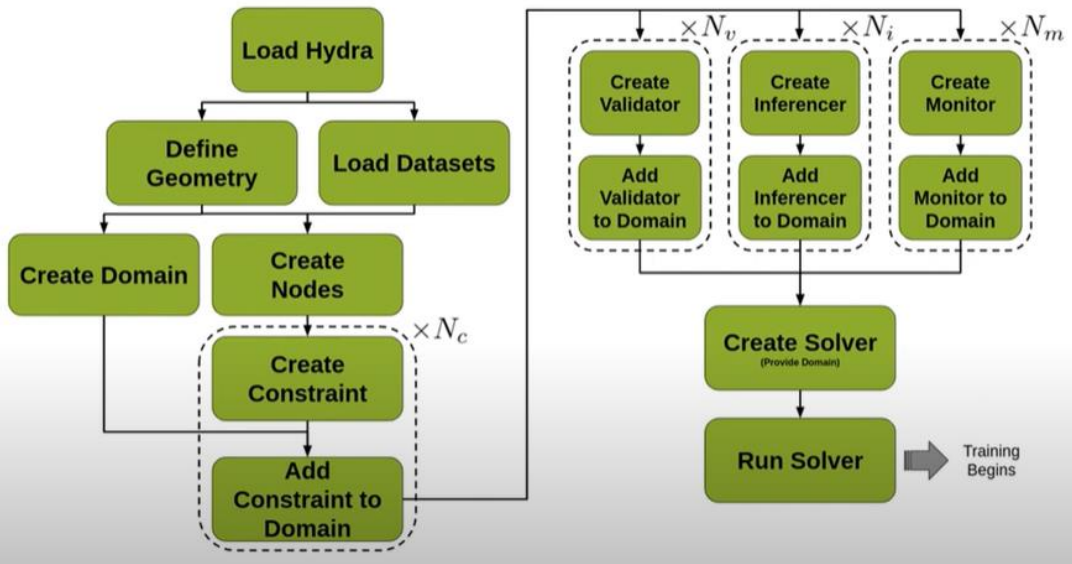
Category I：
物理法則による数値解析による順問題解法
Category II：
物理法則とデータ同化の両方を含むハイブリッド解法
Category III：
物理法則は使わずデータのみを基本とするデータ指向解法

【08】NVIDIA Modulusのソフトウエア構成



形状やデータの定義
↓
ネットワークや
物理法則の定義
↓
制約条件や
損失関数の定義
↓
学習や最適化の処理
↓
設計解の探索
結果の可視化

【09】NVIDIA Modulusの構成要素と開発手順



ハイドラの読込
↓
データセットの読込
↓
形状の定義
↓
ノードの生成
↓
処理手続の生成
↓
処理手続への制約条件の追加
↓
評価機能、推論機能、確認機能の追加
↓
ソルバーの生成
↓
ソルバーの実行

【10】NVIDIA Modulusの導入

「NVIDIA Modulusの導入方法」

効率的なのはDockerイメージを用いる方法、v23.05ではpipも可能になる

「最新版Modulusは３つで構成」

Core, Launch, Symで構成され、本書の機能はModulus-Symで実現する

「例題ファイルexamplesの対応」

公開された1.0.0版はv23.05用であり、v22.09ではモジュール名を変更する

「解説情報Modulus Users Guideの更新」

Modulus Sym User Guideとなり、v22.09はEarlier Releasesとなる

【11】NVIDIA Modulusの動作条件

「ハードウエアの条件」

NVIDIA製GPUが搭載された64bit-x86のPC（それなりの高性能PCが必要）
推奨GPU：　Ampere:A100、A30、RTX A4000 / Volta:V100 / Turing:T4
　　Ampere:RTX 30xx / Volta:Titan V、Quadro GV100
これ以外でも、 Ampere・Volta・Turingなどが動作する可能性あり

「ソフトウエアの条件」

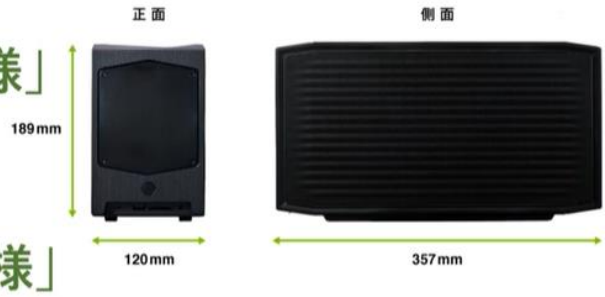
公式ドキュメントでは「Ubuntu 20.04 LTSまたはLinux 5.13 kernel」
基本ツールとしては、「Python 3.8・PyTorch 1.12以上」が必要です
本書ではNVIDIA Modulus v22.09を用いて、構築手順を説明します
この場合には「Python 3.8.13・PyTorch 1.13.0」が利用されている

【12】NVIDIA Modulus検証用ＰＣの説明

本書では個人利用を想定した小型PCを利用（特別な条件はありません）

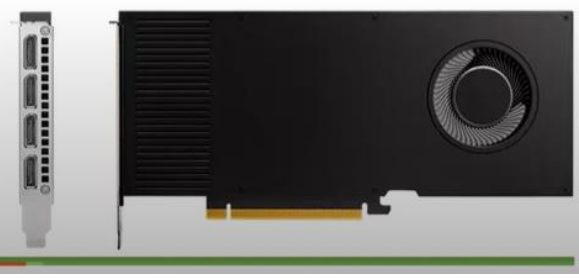
「GWS-i9Miniのハードウエア仕様」

CPU: Intel Core i9-12900 24core
RAM: 64GB　　SSD: 1TB



「GPU: NVIDIA RTX A4500の仕様」

アーキテクチャ: Ampere
VRAM: 20GB GDDR6,
CUDAコア: 7168
Tensorコア:224



【13】Ubuntu20.04-LTSを導入する

「導入の条件」

GPUを利用するので、GPUドライバが導入できDockerで利用できること
WSL2やVirtualBoxなどの仮想環境では、高度な技術が必要かと…
GPU搭載マシンに、デュアルブート含め直接に導入することをお勧めします。

「Ubuntu20.04の導入」

DVDメディアかUSBメモリで、インストールメディアを用意する
BIOS/UEFIの設定を変更して、用意したメディアから起動する設定とする
（新しいPCではセキュアブートの制限に対応する場合もあり）
インストールツールの指示に従って、特別な設定は不要で導入する
インストール直後の、20.04の範囲でのソフトウエアの更新は進める
GPUドライバとの相性があるので、その後は更新は避けたほうが良いかも

【14】NVIDIAドライバをインストールする

「インストールの方法」

GPUの導入方法は、NVIDIAサイトからパッケージを入手して手動で可能です
ただUbuntuの場合は、ubuntu-driversで、お任せで導入する方法が簡単です

「インストールの手順」

端末から、以下のコマンド入力で行います
1: $ ubuntu-drivers devices　PCの搭載されているGPUを確認します
2: 表示がない場合は、$ lspci | grep -i nvidia でGPUを確認します
3: $ sudo ubuntu-drivers install　お勧めのドライバを導入します
4:ドライバを有効にするために再起動します
5: $ nvidia-smi　出力を見て、ドライバのバージョンなどを確認します
（ここが重要で、PCの構成によっては、試行錯誤が必要になります）

【14】NVIDIAドライバをインストールする

「インストールの方法」

GPUの導入方法は、NVIDIAサイトからパッケージを入手して手動で可能です
ただUbuntuの場合は、ubuntu-driversで、お任せで導入する方法が簡単です

「インストールの手順」

端末から、以下のコマンド入力で行います
1: $ ubuntu-drivers devices　PCの搭載されているGPUを確認します
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3: $ sudo ubuntu-drivers install　お勧めのドライバを導入します
4:ドライバを有効にするために再起動します
5: $ nvidia-smi　出力を見て、ドライバのバージョンなどを確認します
（ここが重要で、PCの構成によっては、試行錯誤が必要になります）

【15】UbuntuにDockerをインストールする

「インストールの手順」

端末から、以下のコマンド入力で行います
1: $ sudo apt install curl　ウエブアクセスツールを導入します
2: Dockerの利用に必要なシステムをインストールします
　　curl https://get.docker.com | sh && sudo systemctl --now enable docker
3: NVIDIAのGitHubからダウンロードする検証用 のGPGキーを取得します
4:取得したGPGキーを有効にするために $ sudo apt update でを更新します
5: $ sudo apt install -y nvidia-docker2　GPU利用可能なDockerを導入します
6: $ sudo systemctl restart docker → $ sudo systemctl status docker
7: nvidia-smiコマンドでnvidia-docker2によるGPUの認識を確認します
　　$ sudo docker run --rm --gpus all
　　nvcr.io/nvidia/cuda:11.8.0- base-ubuntu20.04 nvidia-smi

【16】ModulusのDockerイメージや例題examplesを入手する

「Dockerイメージの入手」

NVIDIA Modulusの公式サイトに接続し、「Download Now」のリンクに進む
現在利用可能な 4 つのイメージ（23.05, 22.09, 22.07, 22.03.1）が並ぶ
本書ではv22.09を、docker pull nvcr.io/nvidia/modulus/modulus:22.09 で入手
正しく入手できたかを、docker imagesで以下のイメージを確認する
　　REPOSITORYT: nvcr.io/nvidia/modulus/modulus　　TAG: 22.09

「例題examplesの入手」

NVIDIA ModulusのGitHub「NVIDIA/modulus-sym Public」サイトに接続する
Releasesの項目のv1.0.0として、modulus-sym-1.0.0.zip(158MB)を入手する
この例題ファイルは、最新版v23.05のModulus-Symに対応している

【17】Modulusの必要なファイルを準備し起動確認する

「起動確認の手順」

端末から、以下のコマンド入力で行います

1: $ unzip modulus-sym-1.0.0.zip modulus-sym用ファイルを展開する

2: 展開してできたmodulus-sym-1.0.0/の中に例題ファイルexamplesがある

3: Modulus用Dockerイメージを例題ファイルに接続して起動します

```
docker run --shm-size=1g --ulimit memlock=-1 --ulimit
stack=67108864 ¥
 --runtime nvidia -v ${PWD}/examples:/examples ¥
 -it nvcr.io/nvidia/modulus/modulus:22.09 bash
```

4:Docker内で以下の構成のNVIDIA Modulusの起動が確認できる

```
NVIDIA Release 22.08 (build 42105213)
PyTorch Version 1.13.0a0+d321be6
```

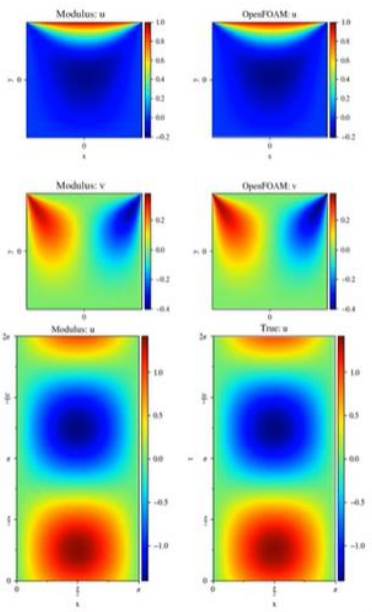
【19】第２章　基本例題：動作確認例題と微分方程式の記述の紹介

「Lid Driven Cavity Background」：２次元矩形空間でのキャビティ流れの確認

正方形２次元空間での上部壁駆動によるキャビティ
流体解析の基本的な例題の１つでCFD結果と比較
最初の例題としてModulusの活用方法の全体を学ぶ
OpenFOAMと比較検討し良い一致を確認できる

「1D Wave Equation」：1次元波動方程式の解法

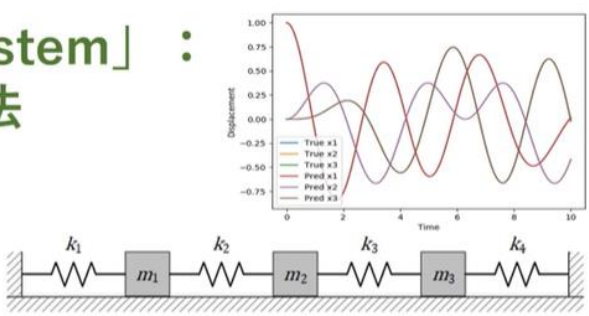
偏微分方程式をModulusで記述する方法を確認する
時間依存（非定常）の問題解法について具体化する
解析的な結果から評価用データを生成する方法
時間結果によって推定誤差の変化を確認できる



【20】第３章　構造例題：質点系振動問題と弾性構造物の挙動の紹介

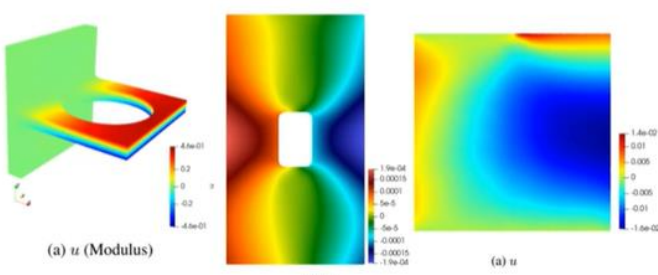
「Coupled Spring Mass ODE System」：多質点系での力学的振動問題の解法

バネと質点による多質点系の力学的振動問題
連立した常微分方程式を用いた非定常解法
バネ定数や質点質量をパラメータにもできる
数学的な結果と完全に一致することを確認



「Linear Elasticity」：３次元構造物の弾性挙動の分析

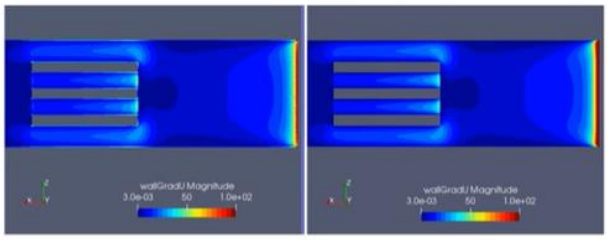
問題１：ブラケット部品の変形状態
問題２：航空機機体パネルの応力解析
問題３：正方形薄板の面内変形
標準的な有限要素法の解析結果と一致



【21】第４章　流体例題：共役熱伝導解析と工学的熱伝導問題の紹介

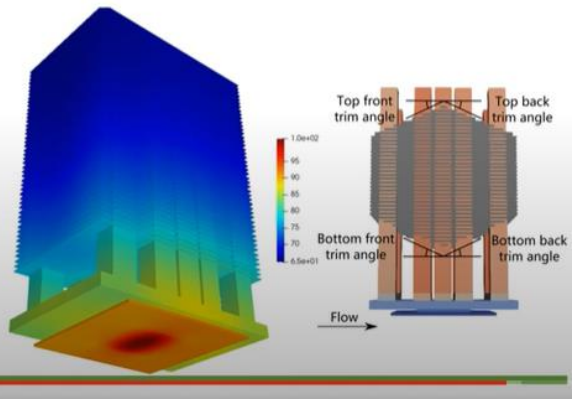
「Conjugate Heat Transfer」：共役熱伝導問題の解析手順

ヒートシンクと流体の間での共役熱伝導問題
相互作用の境界条件を用いた問題解決手法
片方向連成問題に対するマルチフェーズ学習
OpenFOAMの結果と比較して良い一致



「Industrial Heat Sink」：工学的熱伝導問題の解析手順

工学的な応用例題のヒートシンクの熱挙動
共役熱伝導問題を解くためのhFTBアルゴリズム
転移学習を用いたサロゲートモデルによるgPC
圧力低下の相対誤差が１%以下の良い精度



【23】まとめと謝辞

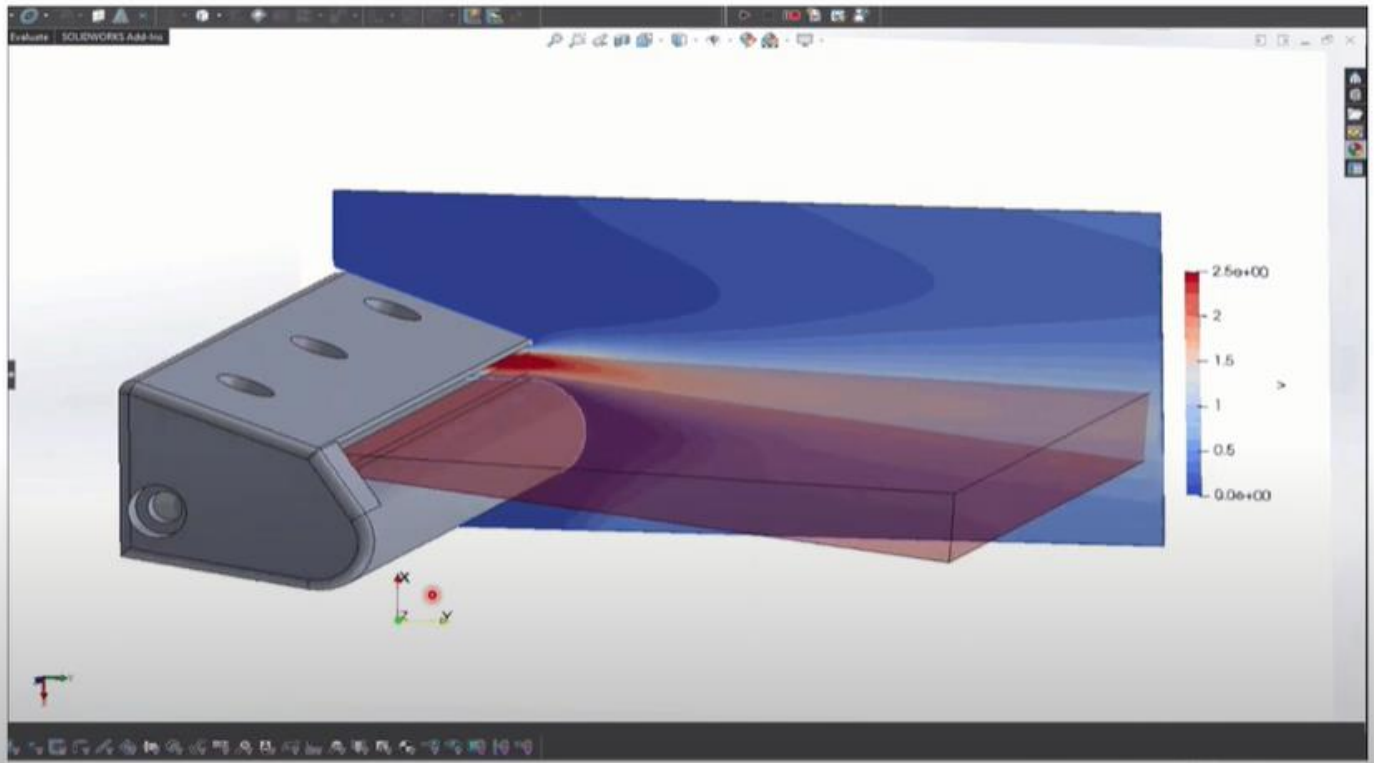
「まとめ」

CAEとAIを融合した新しい問題解決手段として、Physics-MLに期待します
PINNsなどを効率的に実現する手段として、NVIDIA Modulusはお薦めです
NVIDIA GPUが搭載されたPCがあれば、誰でも無償で手軽に検証できます
本書はNVIDIA Modulusの環境構築を確実に実現する構築手順を提示します
多彩な例題と詳細な文書が提供されており、ここから実践的に学べます

「謝辞」

本書の作成に当たっては、NVIDIA様の全面的ご協力として、監修をいただき、技術面では丹愛彦さま、古家真之介さま、広報では中村かおりさま、そして統括として廣岡信行さまには、大変にお世話になりました。皆様にお礼申し上げます。

Accelerating Product Development With Physics-ML

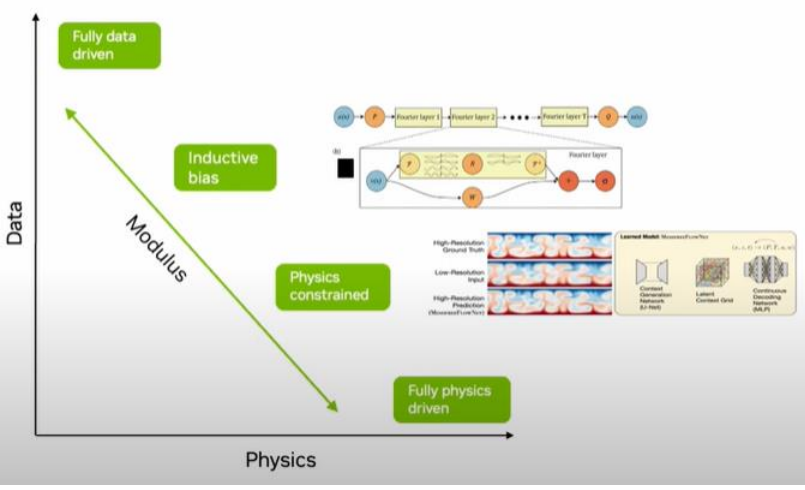


Kinetic Vision | DS Fluent, SolidWorks -- https://www.youtube.com/watch?v=qJtJbloWb4M

https://developer.nvidia.com/blog/accelerating-product-development-with-physics-informed-neural-networks-and-modulus/

Open-Source Toolkit for Physics-ML

Novel NN architectures



Diverse Physics-ML approaches - Model Zoo:

- PDE driven Physics-ML recipes
- Data driven Physics-ML recipes
- Hybrid (Data + PDE) Physics-ML recipes

PDE Driven - PINNs:

- Fourier Feature Network
- Spatial-temporal Fourier Feature Networks
- Super Resolution Net ...

Data Driven - Neural Operators:

- Fourier Neural Operator family (FNO, AFNO, Nested)
- DeepONet

GNNs:

- MeshGraphNet
- GraphCast

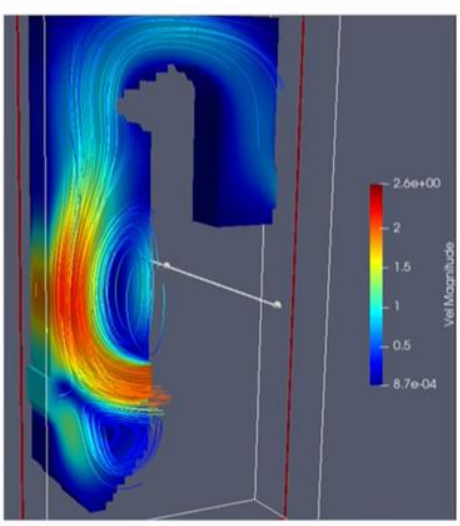
Hybrid: PINO, ..

Developing Digital Twins With Physics-ML

Industrial Digital Twins

Siemens Energy HRSG
PINN | Coupled Flows, Physics

Siemens Gamesa Windfarm
PINN/GAN | Super-Resolution

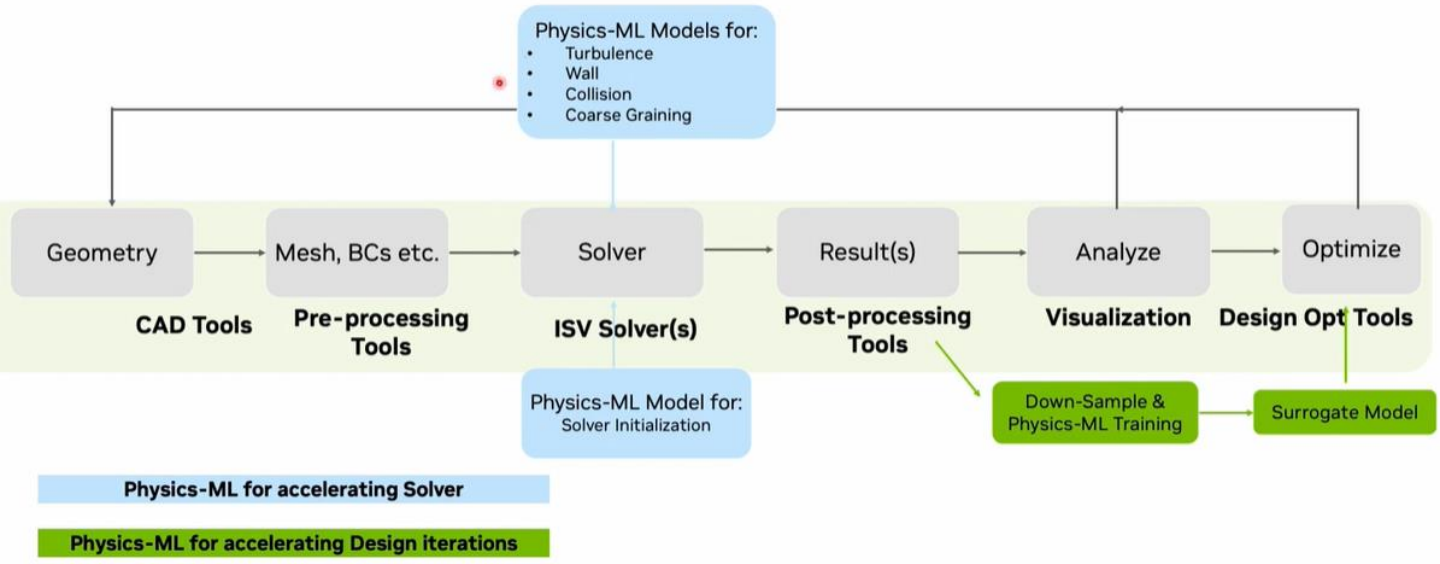


NETL Power Plant Boiler
PINN | Multi-Physics, Custom Training

https://resources.nvidia.com/l/en-us-modulus-pathfactory-explore-page

Simulation Acceleration With Modulus

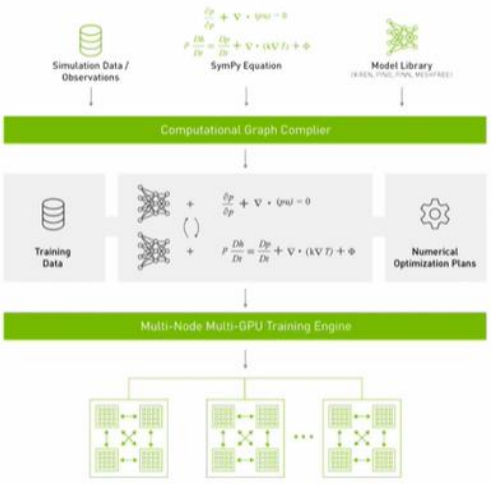
Physics-ML Augmented Simulation Workflows



Open-Source Toolkit for Physics-ML

NVIDIA Modulus

- A customizable platform - training and inference pipeline - using Physics (governing equations) and Data (simulation/observations)
- Python based APIs for ease of use
- Facilitates open collaboration within the Physics-ML scientific community
- Well documented features and functionality for ease of use
- Open-source code – easier to understand and customize
- Import PyTorch models from research for your custom application



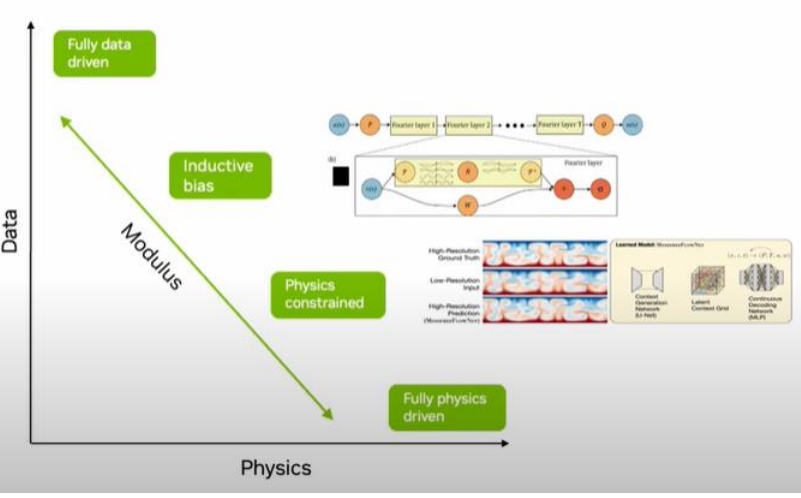
Source code:

- https://github.com/NVIDIA/Modulus
- https://github.com/NVIDIA/modulus-launch
- https://github.com/NVIDIA/modulus-toolchain
- https://github.com/NVIDIA/modulus-sym

NVIDIA

Open-Source Toolkit for Physics-ML

Novel NN architectures



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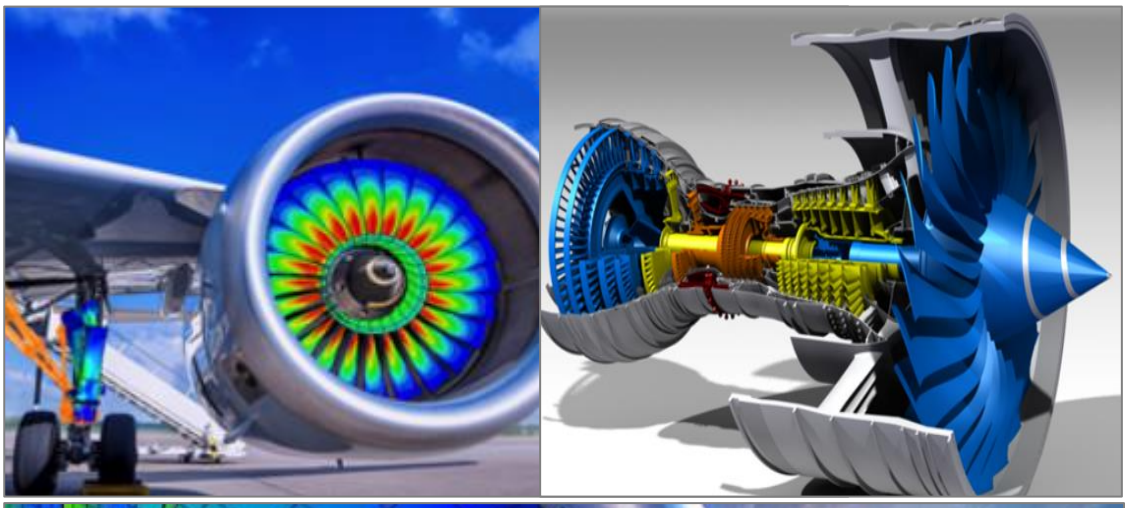
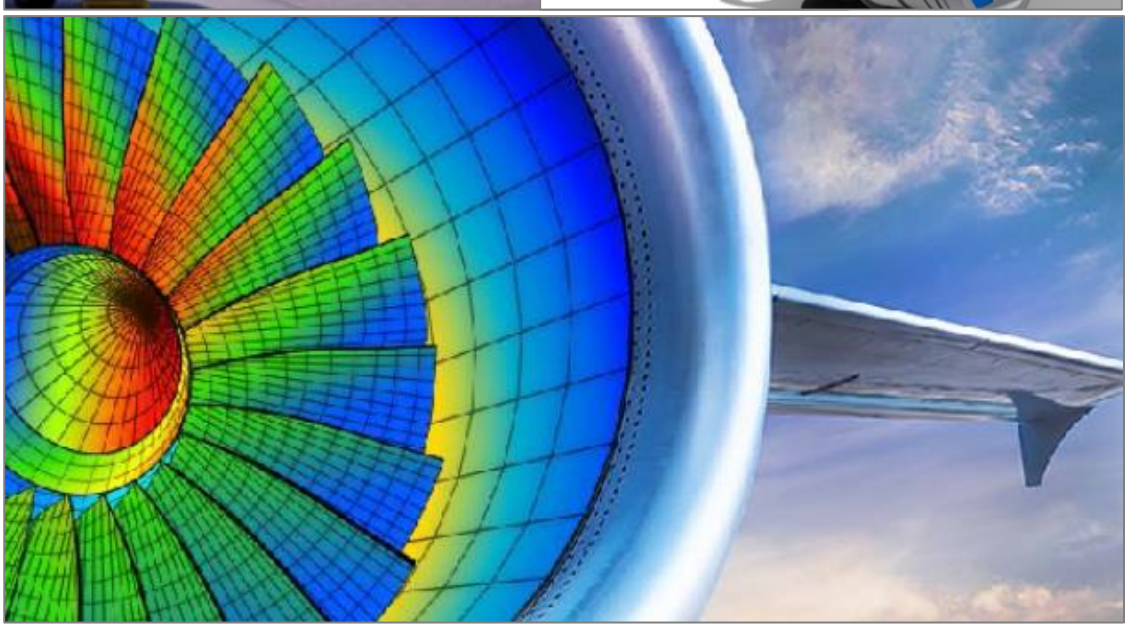
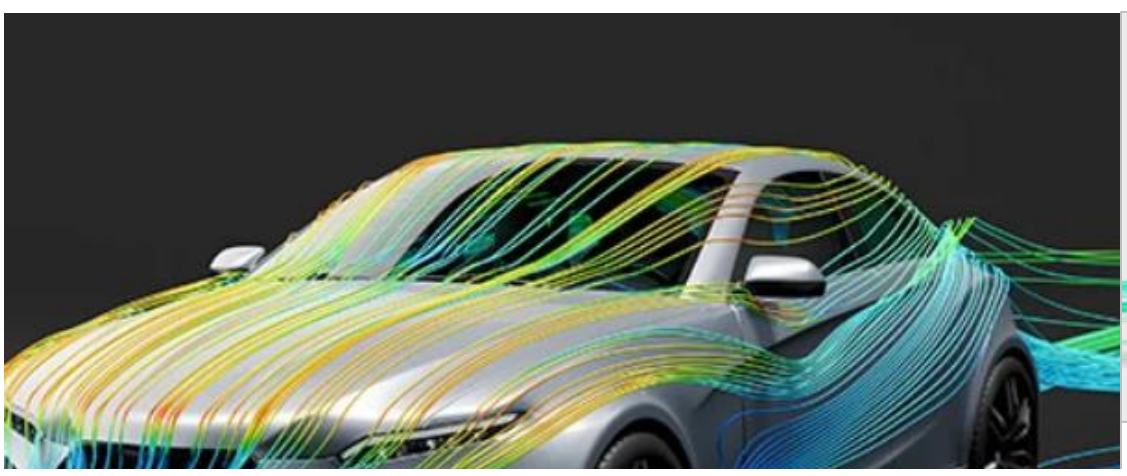
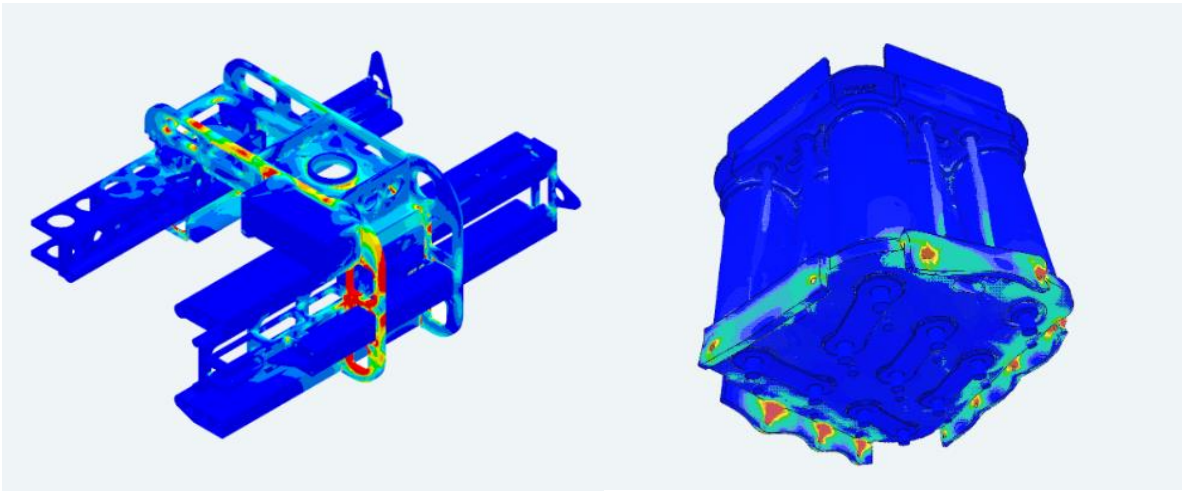
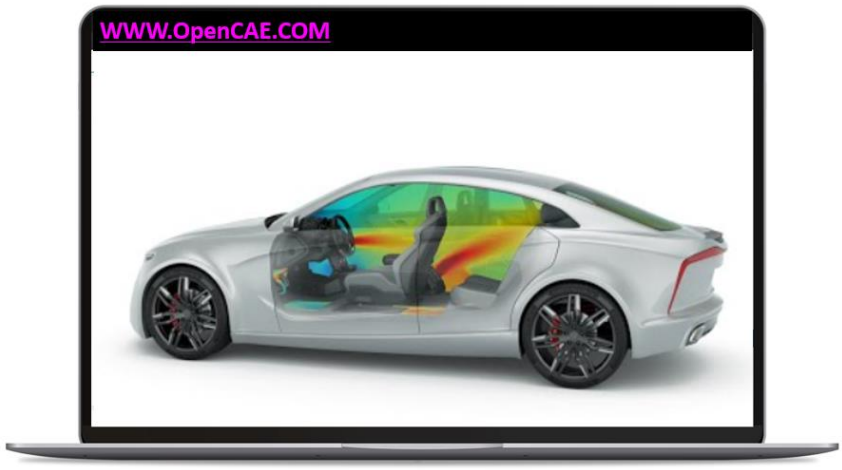




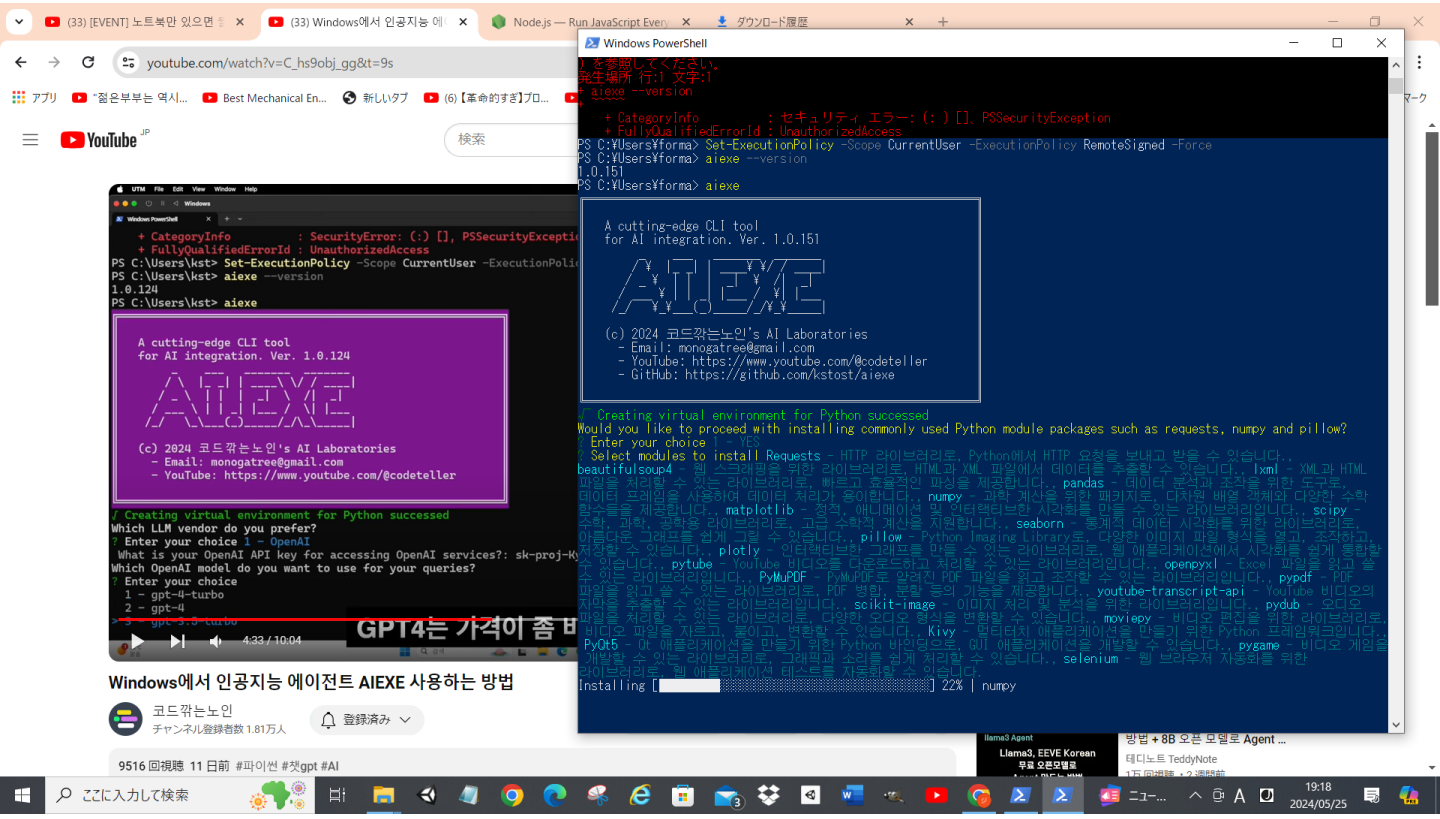


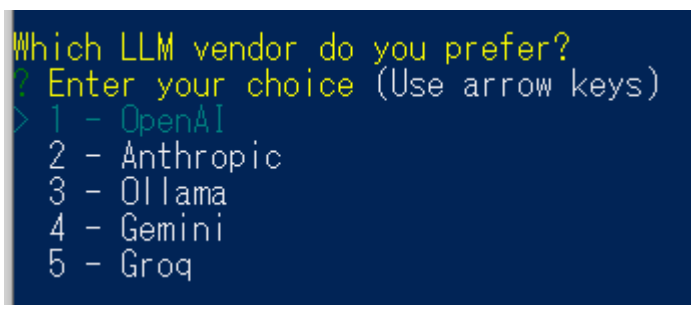


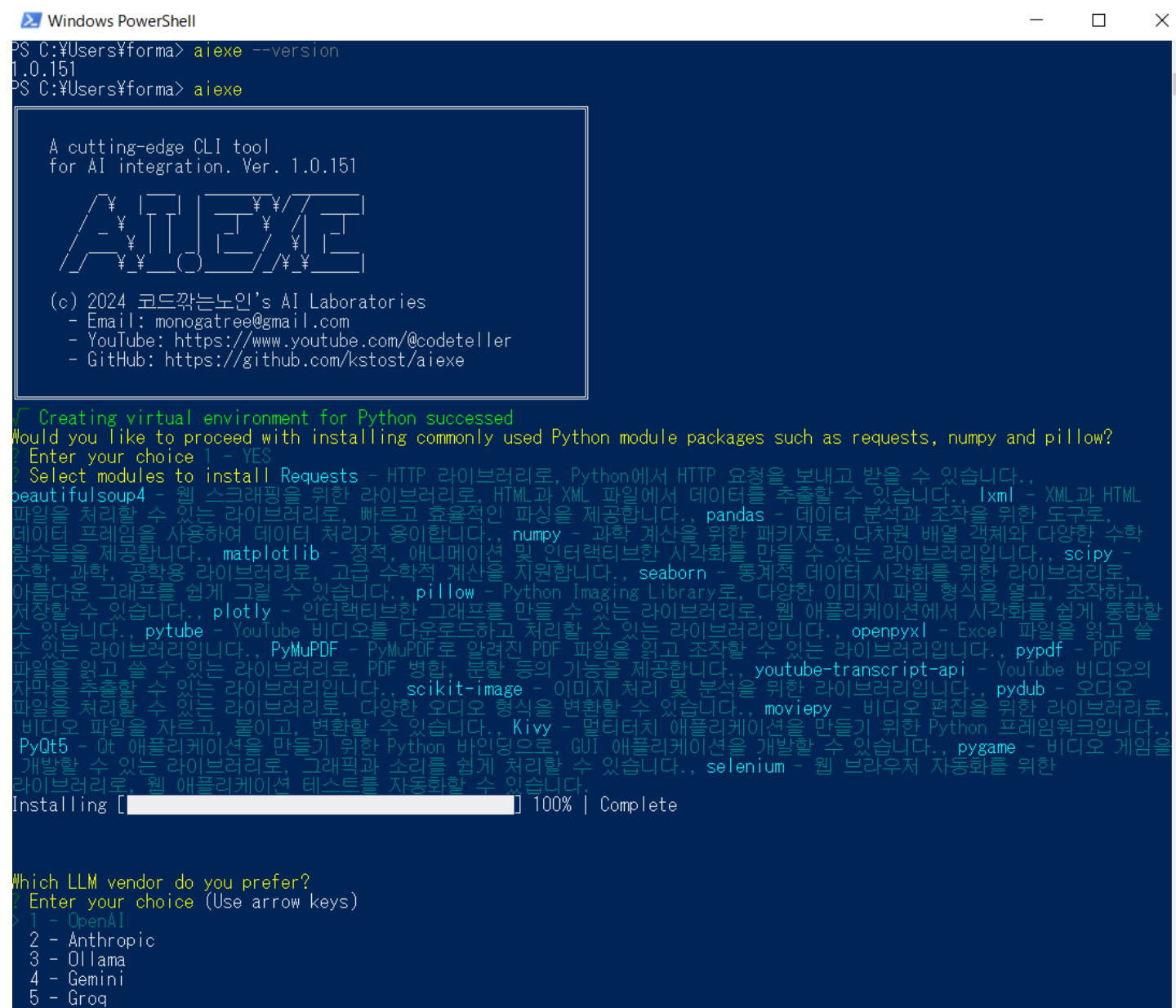
OpenX



OpenX


Windows PowerShell
PS C:¥Users¥forma> Set-ExecutionPolicy -Scope CurrentUser -ExecutionPolicy RemoteSigned -Force
PS C:¥Users¥forma> aiexe --version
1.0.151
PS C:¥Users¥forma> aiexe
A cutting-edge CLI tool
for AI integration. Ver. 1.0.151
(c) 2024 코드깎는노인's AI Laboratories
- Email: monogatree@gmail.com
- YouTube: https://www.youtube.com/@codeteller
- GitHub: https://github.com/kstost/aiexe
√ Creating virtual environment for Python successed
Would you like to proceed with installing commonly used Python module packages such as requests, numpy and pillow?
? Enter your choice 1 - YES
? Select modules to install Requests - HTTP 라이브러리로, Python에서 HTTP 요청을 보내고 받을 수 있습니다., beautifulsoup4 - 웹 스크래핑을 위한 라이브러리로, HTML과 XML 파일에서 데이터를 추출할 수 있습니다., lxml - XML과 HTML 파일을 처리할 수 있는 라이브러리로, 빠르고 효율적인 파싱을 제공합니다., pandas - 데이터 분석과 조작을 위한 도구로, 데이터 프레임을 사용하여 데이터 처리가 용이합니다., numpy - 과학 계산을 위한 패키지로, 다차원 배열 객체와 다양한 수학 함수들을 제공합니다., matplotlib - 정적, 애니메이션 및 인터랙티브한 시각화를 만들 수 있는 라이브러리입니다., scipy - 수학, 과학, 공학용 라이브러리로, 고급 수학적 계산을 지원합니다., seaborn - 통계적 데이터 시각화를 위한 라이브러리로, 아름다운 그래프를 쉽게 그릴 수 있습니다., pillow - Python Imaging Library로, 다양한 이미지 파일 형식을 열고, 조작하고, 저장할 수 있습니다., plotly - 인터랙티브한 그래프를 만들 수 있는 라이브러리로, 웹 애플리케이션에서 시각화를 쉽게 통합할 수 있습니다., pytube - YouTube 비디오를 다운로드하고 처리할 수 있는 라이브러리입니다., openpyxl - Excel 파일을 읽고 쓸 수 있는 라이브러리입니다., PyMuPDF - PyMuPDF로 알려진 PDF 파일을 읽고 조작할 수 있는 라이브러리입니다., pypdf - PDF 파일을 읽고 쓸 수 있는 라이브러리로, PDF 병합, 분할 등의 기능을 제공합니다., youtube-transcript-api - YouTube 비디오의 자막을 추출할 수 있는 라이브러리입니다., scikit-image - 이미지 처리 및 분석을 위한 라이브러리입니다., pydub - 오디오 파일을 처리할 수 있는 라이브러리로, 다양한 오디오 형식을 변환할 수 있습니다., moviepy - 비디오 편집을 위한 라이브러리로, 비디오 파일을 자르고, 붙이고, 변환할 수 있습니다., Kivy - 멀티터치 애플리케이션을 만들기 위한 Python 프레임워크입니다., PyQt5 - Qt 애플리케이션을 만들기 위한 Python 바인딩으로, GUI 애플리케이션을 개발할 수 있습니다., pygame - 비디오 게임을 개발할 수 있는 라이브러리로, 그래픽과 소리를 쉽게 처리할 수 있습니다., selenium - 웹 브라우저 자동화를 위한 라이브러리로, 웹 애플리케이션 테스트를 자동화할 수 있습니다.
Installing [] 22% | numpy
Windows에서 인공지능 에이전트 AIEXE 사용하는 방법
코드깎는노인
9516 回視聴 11 日前 #파이썬 #챗gpt #AI


Which LLM vendor do you prefer?
? Enter your choice (Use arrow keys)
> 1 - OpenAI
2 - Anthropic
3 - Ollama
4 - Gemini
5 - Groq


Windows PowerShell
PS C:¥Users¥forma> aiexe --version
1.0.151
PS C:¥Users¥forma> aiexe
A cutting-edge CLI tool
for AI integration. Ver. 1.0.151
(c) 2024 코드깎는노인's AI Laboratories
- Email: monogatree@gmail.com
- YouTube: https://www.youtube.com/@codeteller
- GitHub: https://github.com/kstost/aiexe
√ Creating virtual environment for Python successed
Would you like to proceed with installing commonly used Python module packages such as requests, numpy and pillow?
? Enter your choice 1 - YES
? Select modules to install Requests - HTTP 라이브러리로, Python에서 HTTP 요청을 보내고 받을 수 있습니다., beautifulsoup4 - 웹 스크래핑을 위한 라이브러리로, HTML과 XML 파일에서 데이터를 추출할 수 있습니다., lxml - XML과 HTML 파일을 처리할 수 있는 라이브러리로, 빠르고 효율적인 파싱을 제공합니다., pandas - 데이터 분석과 조작을 위한 도구로, 데이터 프레임을 사용하여 데이터 처리가 용이합니다., numpy - 과학 계산을 위한 패키지로, 다차원 배열 객체와 다양한 수학 함수들을 제공합니다., matplotlib - 정적, 애니메이션 및 인터랙티브한 시각화를 만들 수 있는 라이브러리입니다., scipy - 수학, 과학, 공학용 라이브러리로, 고급 수학적 계산을 지원합니다., seaborn - 통계적 데이터 시각화를 위한 라이브러리로, 아름다운 그래프를 쉽게 그릴 수 있습니다., pillow - Python Imaging Library로, 다양한 이미지 파일 형식을 열고, 조작하고, 저장할 수 있습니다., plotly - 인터랙티브한 그래프를 만들 수 있는 라이브러리로, 웹 애플리케이션에서 시각화를 쉽게 통합할 수 있습니다., pytube - YouTube 비디오를 다운로드하고 처리할 수 있는 라이브러리입니다., openpyxl - Excel 파일을 읽고 쓸 수 있는 라이브러리입니다., PyMuPDF - PyMuPDF로 알려진 PDF 파일을 읽고 조작할 수 있는 라이브러리입니다., pypdf - PDF 파일을 읽고 쓸 수 있는 라이브러리로, PDF 병합, 분할 등의 기능을 제공합니다., youtube-transcript-api - YouTube 비디오의 자막을 추출할 수 있는 라이브러리입니다., scikit-image - 이미지 처리 및 분석을 위한 라이브러리입니다., pydub - 오디오 파일을 처리할 수 있는 라이브러리로, 다양한 오디오 형식을 변환할 수 있습니다., moviepy - 비디오 편집을 위한 라이브러리로, 비디오 파일을 자르고, 붙이고, 변환할 수 있습니다., Kivy - 멀티터치 애플리케이션을 만들기 위한 Python 프레임워크입니다., PyQt5 - Qt 애플리케이션을 만들기 위한 Python 바인딩으로, GUI 애플리케이션을 개발할 수 있습니다., pygame - 비디오 게임을 개발할 수 있는 라이브러리로, 그래픽과 소리를 쉽게 처리할 수 있습니다., selenium - 웹 브라우저 자동화를 위한 라이브러리로, 웹 애플리케이션 테스트를 자동화할 수 있습니다.
Installing [] 100% | Complete
Which LLM vendor do you prefer?
? Enter your choice (Use arrow keys)
> 1 - OpenAI
2 - Anthropic
3 - Ollama
4 - Gemini
5 - Groq