

DIGIMAN

Soluzioni per la DIGItalizzazione delle aziende nel Settore MANifatturiero

Prognostics and Health Management nel mondo manifatturiero: ausiliari macchina ed usura utensili

MANUTENZIONI A CONFRONTO

REATTIVA



- Intervento dopo il guasto
- Alti costi di manutenzione
- Alti costi di mancata produzione



PREVENTIVA

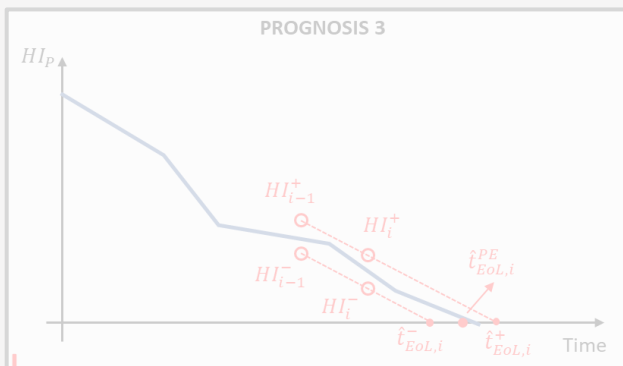
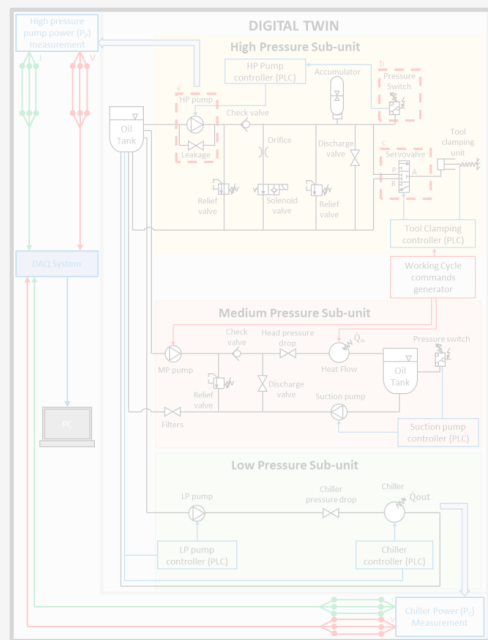
- Intervento pianificato
- Alti costi di mancata produzione
- Fermi macchina ridondanti

PREDITTIVA

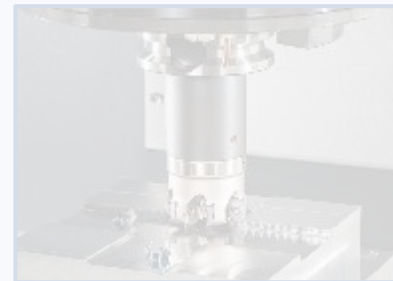


- Intervento basato sulla stima del tempo residuo di vita
- Bassi costi di mancata produzione
- Bassi costi di manutenzione
- Maggiori costi di investimento

MAPPA DELLE ATTIVITÀ



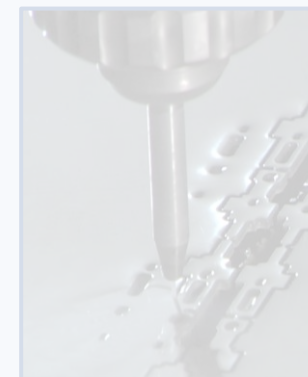
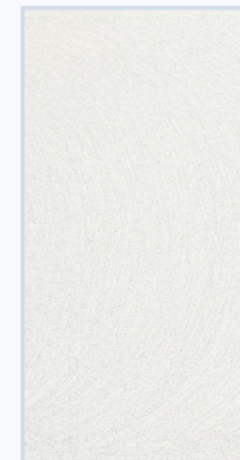
CENTRALINA IDRAULICA



Fresatura



Foratura



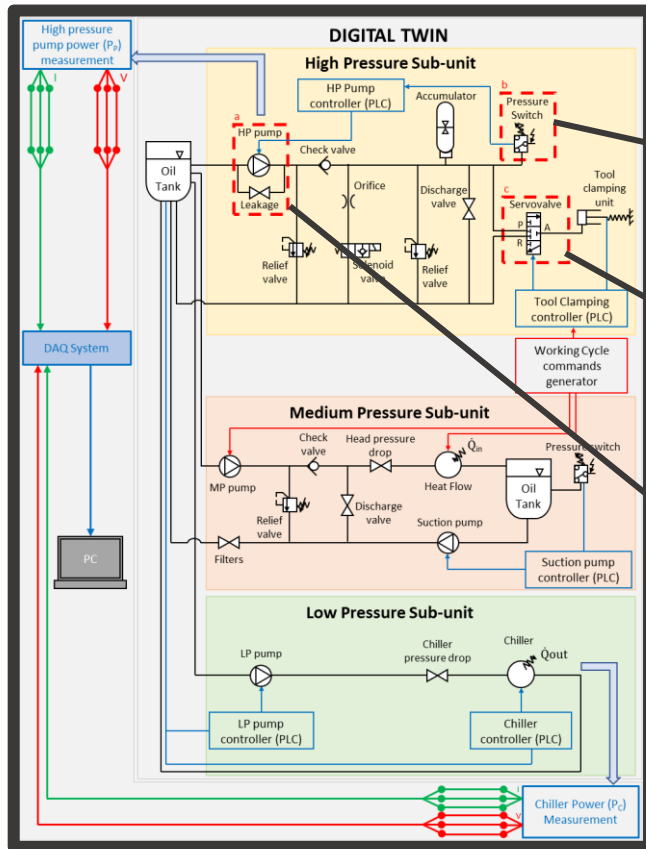
Water Jet

Firma tecnologica ed
inferenza processo

TOOL WEAR

CENTRALINA IDRAULICA: LE SFIDE

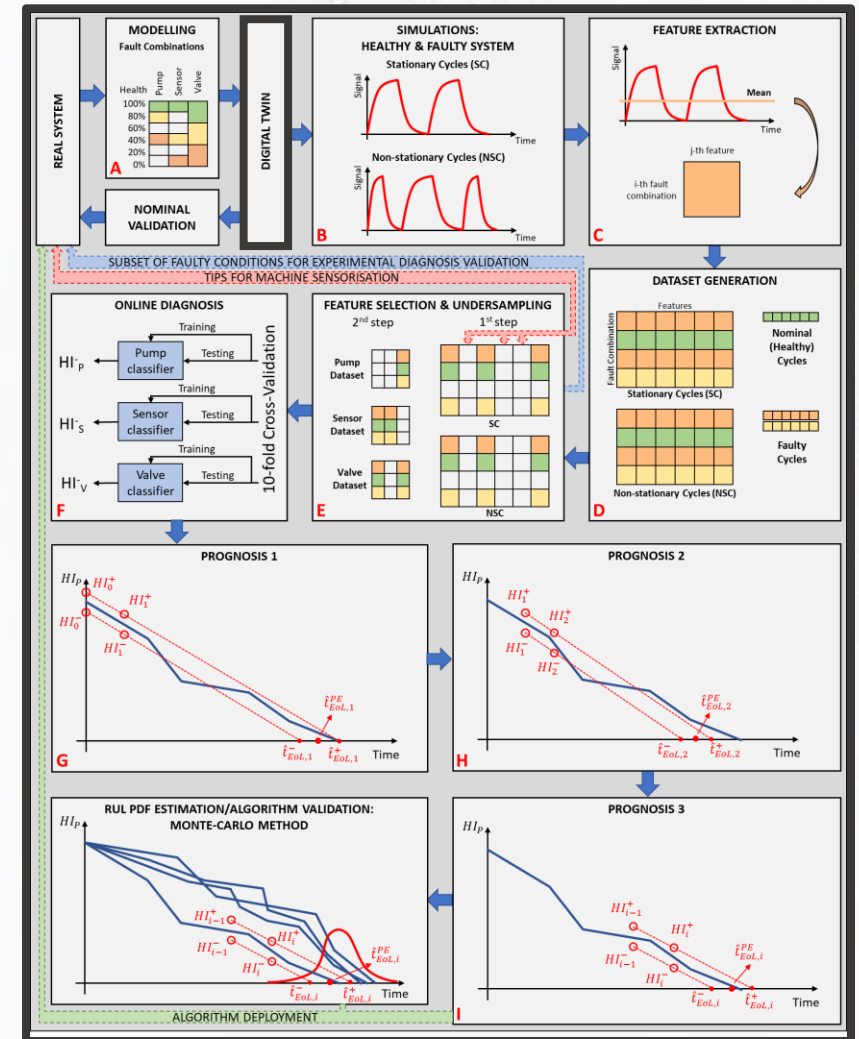
- Variabilità del regime operativo
- Onerosità delle campagne sperimentali (dati di guasto)
- Interazione tra guasti



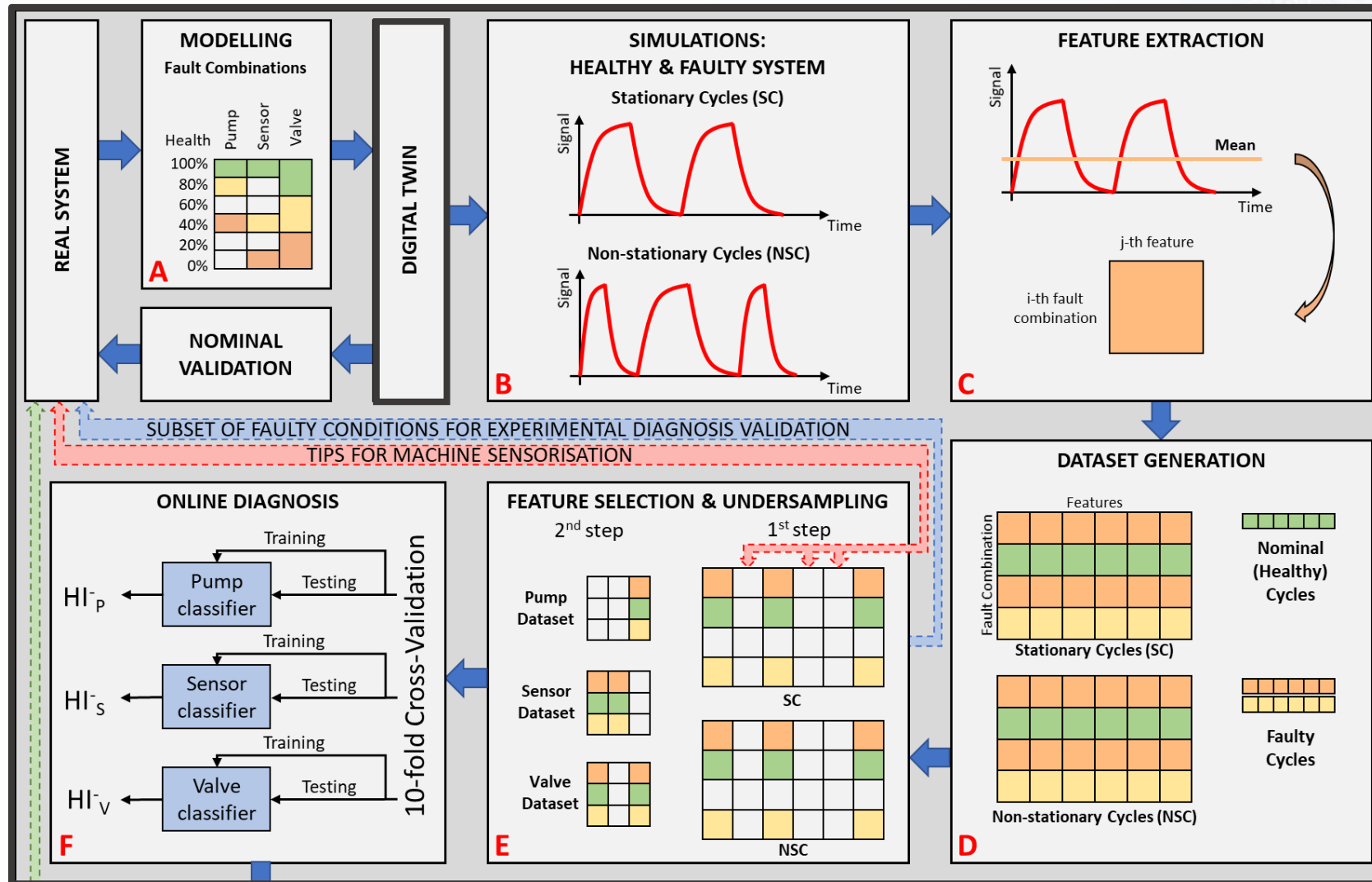
Sensore di pressione

Servo-valvola

Pompa alta-pressione



CENTRALINA IDRAULICA: LA SOLUZIONE



CENTRALINA IDRAULICA: CONCLUSIONI

- **Test d'usura non necessari per la prognostica**
- **Interazione guasti e due regime operativi**
- **Distribuzione RUL e analisi performance**



Guidata da output diagnostica



Combinazione guasti nelle simulazioni del dataset



Simulazioni Monte-Carlo

1. Bernini L, Waltz D, Albertelli P, Monno M. A novel prognostics solution for machine tool sub-units: The hydraulic case. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. December 2021. doi:[10.1177/095440542111064682](https://doi.org/10.1177/095440542111064682)

USURA UTENSILI: FRESATURA



Previsioni
sulle forze medie

$$F_x = \sum a(\phi_j) a_{\phi_j} (F_x \sin(\phi_j) (K_{12} + K_{13}))$$
$$F_y = \sum a(\phi_j) a_{\phi_j} (F_x \cos(\phi_j) (K_{12} + K_{13}))$$



Modello Force Distribution Prediction

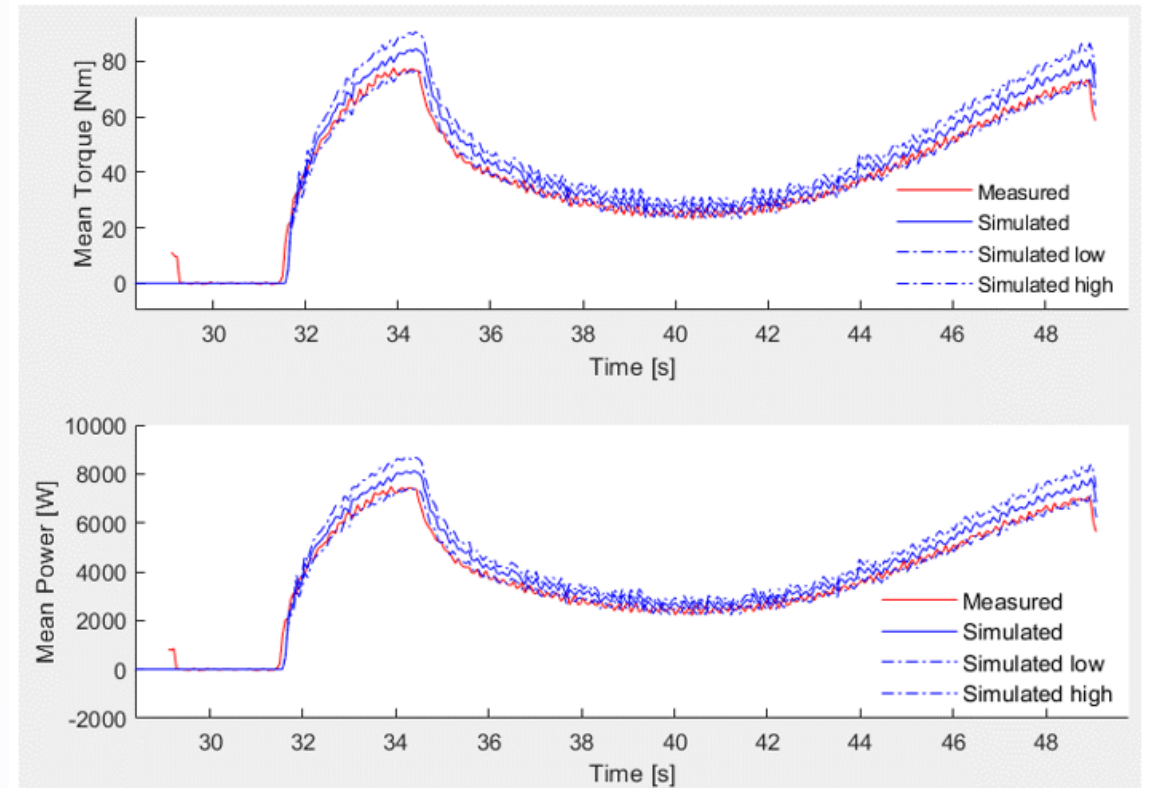
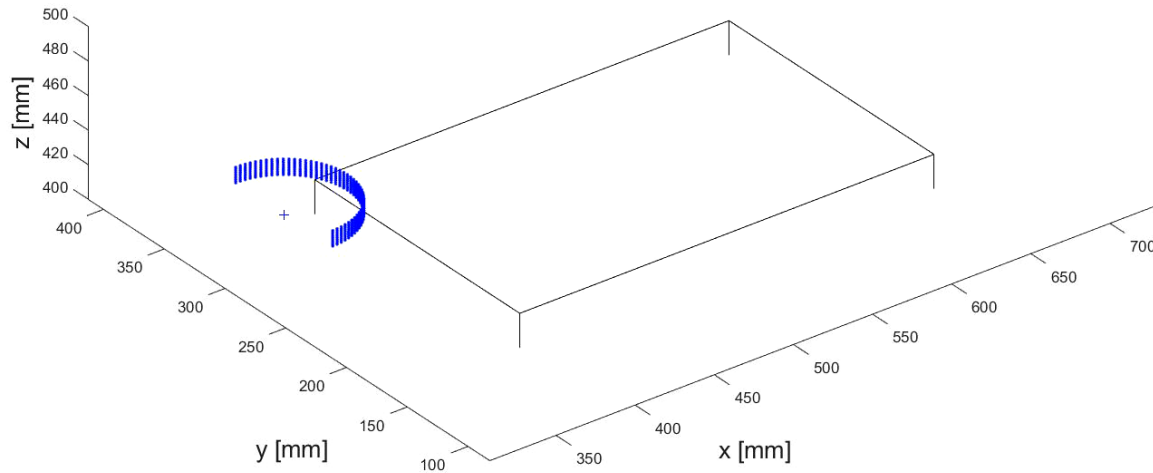


- Sfide SoA:**
- Indipendenza condizioni operative
 - Identificazione SFC – forze istantanee



MODULO DI STIMA INGAGGIO UTENSILE

Mill engagement estimation



IDENTIFICAZIONE SFC E MONITORAGGIO

Regressione forze istantanee

Engagement
estimate module

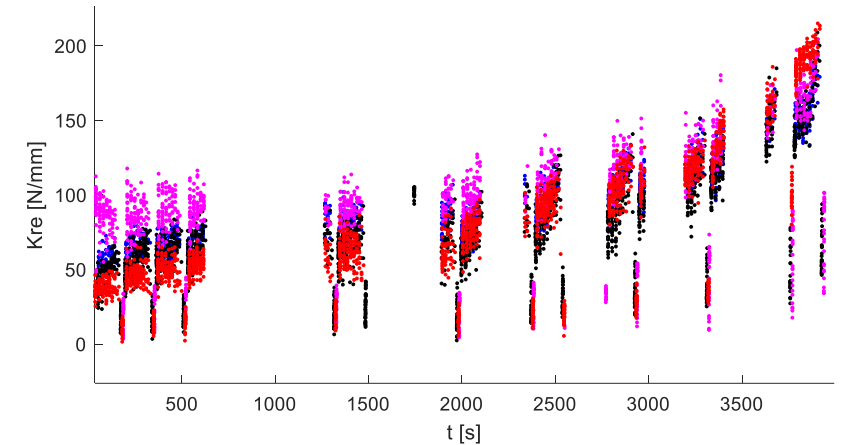
$$F_t = \sum_j g(\phi_j) a_p (f_z \sin(\phi_j) K_{t,c} + K_{t,e})$$

$$F_r = \sum_j g(\phi_j) a_p (f_z \sin(\phi_j) K_{r,c} + K_{r,e})$$

SFC

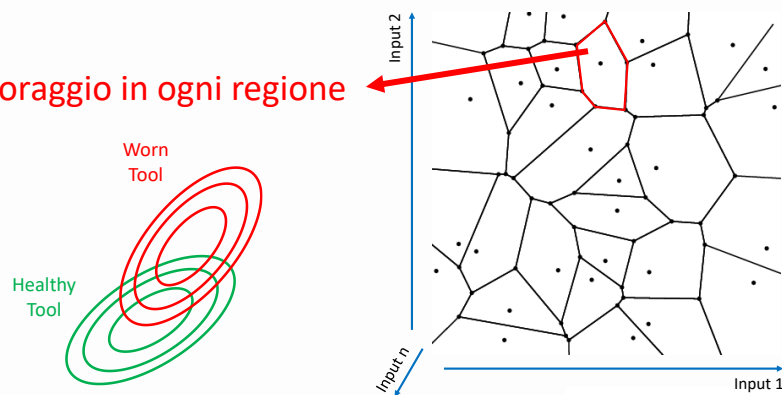


Identificazione SFC

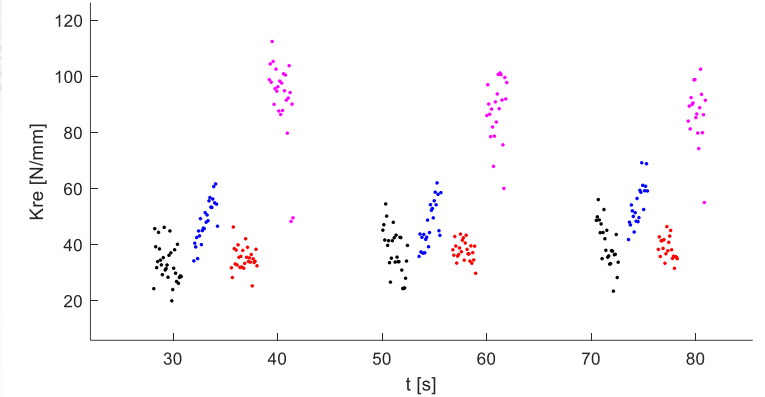


Growing Self Organizing Map (GSOM)

Monitoraggio in ogni regione

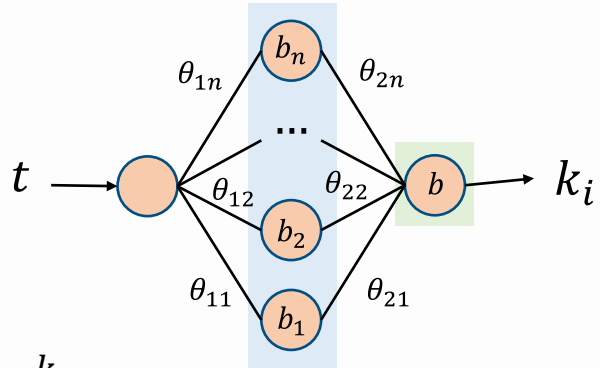


Variabilità Residua

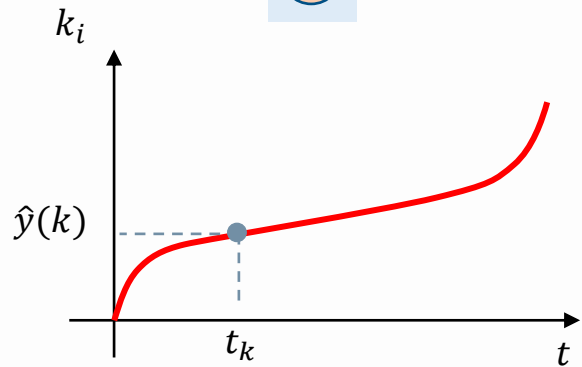


MODULO PROGOSTICA IBRIDA

Multi-Layer Perceptron (MLP)



$$\mathbf{x}(k) = \begin{bmatrix} \boldsymbol{\theta}(k) \\ \mathbf{b}(k) \end{bmatrix}$$

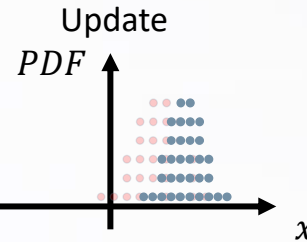
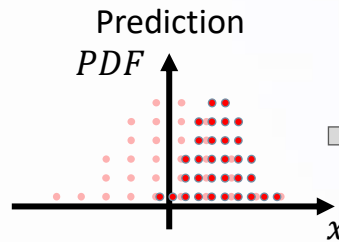
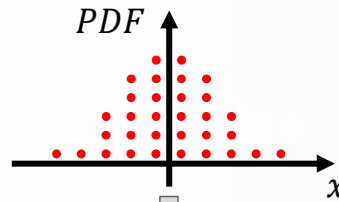


L'MLP è addestrato inizialmente con uno (o più) test d'usura

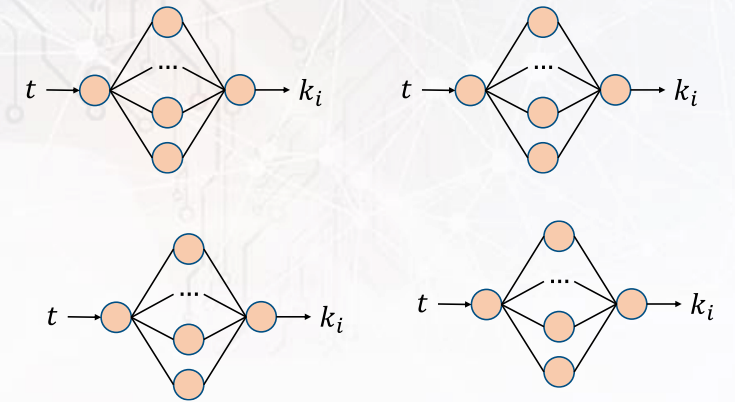
Particle Filter

$$\begin{cases} \mathbf{x}^-(k) = \mathbf{x}^+(k-1) + \boldsymbol{\omega}_{k-1} & \text{Equazione di processo} \\ \mathbf{y}(k) = k_i(t(k), \mathbf{x}^-(k)) + \eta(k) & \text{Equazione di misura} \\ \mathcal{L}(\mathbf{y}_{0:k} | \mathbf{x}(k)) \rightarrow \mathbf{x}^+(k) & \text{Aggiornamento} \end{cases}$$

Distribuzione iniziale di MLP (approssimata da particelle)

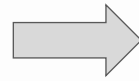


Ogni particella crea un MLP



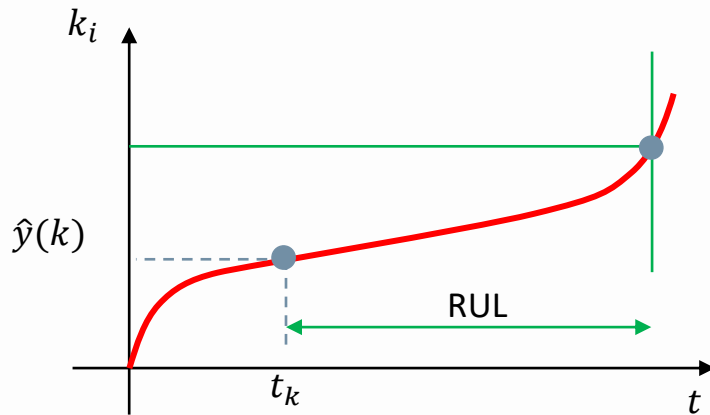
MODULO PROGOSTICA IBRIDA: RISULTATI

Gli MLP sono addestrati con i dati misurati (da modulo stima SFC)

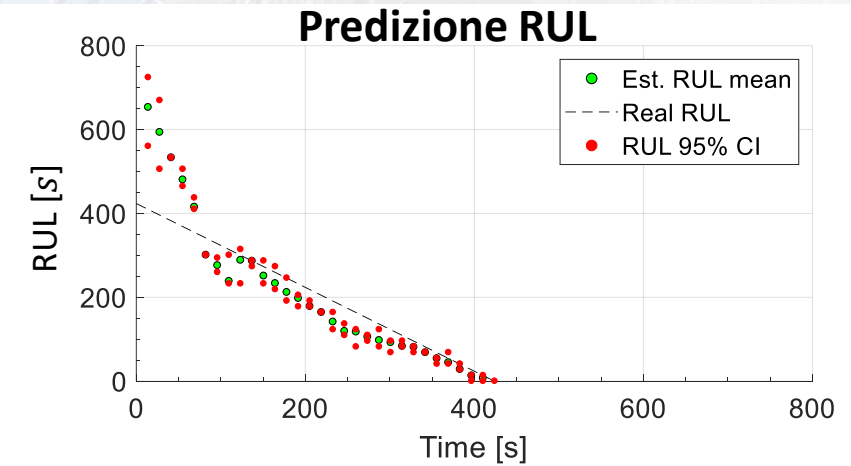
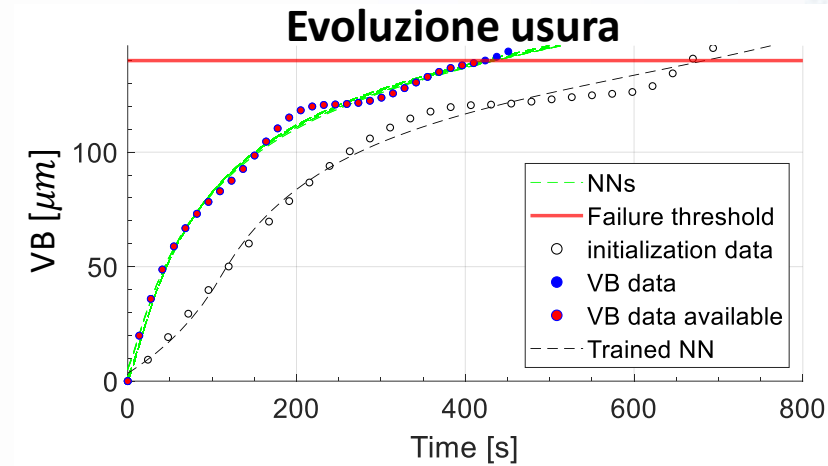
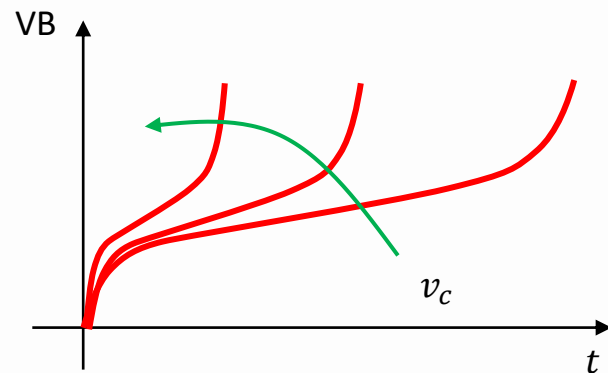


Algoritmo adattivo per gestire le condizioni operative:

- Velocità di taglio
- Condizioni di lubrificazione
- Materiali differenti

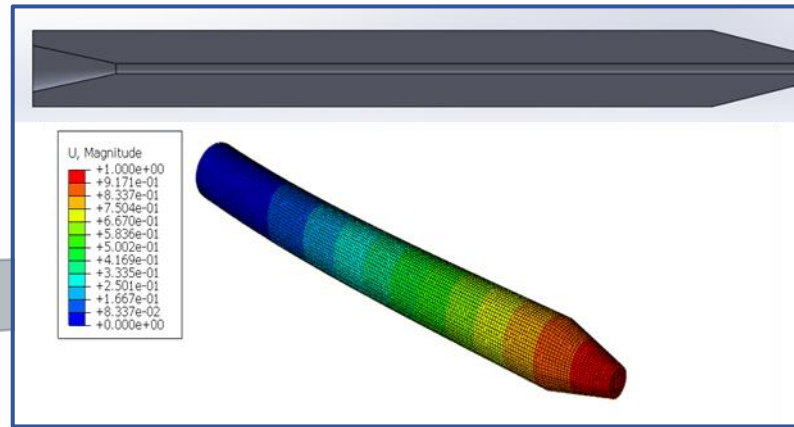


Remaining Useful Life (RUL)



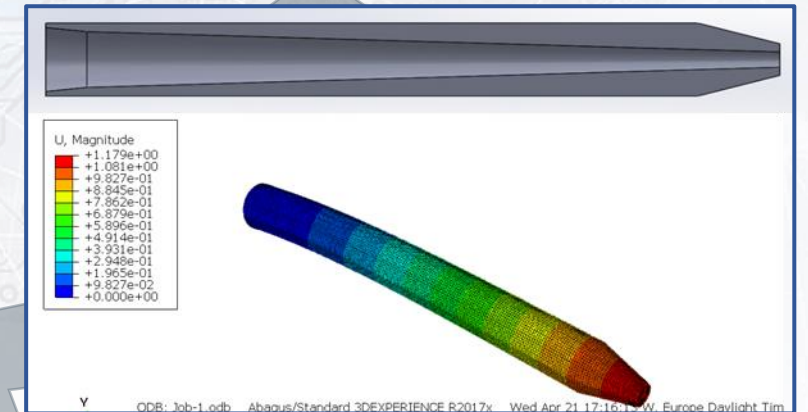
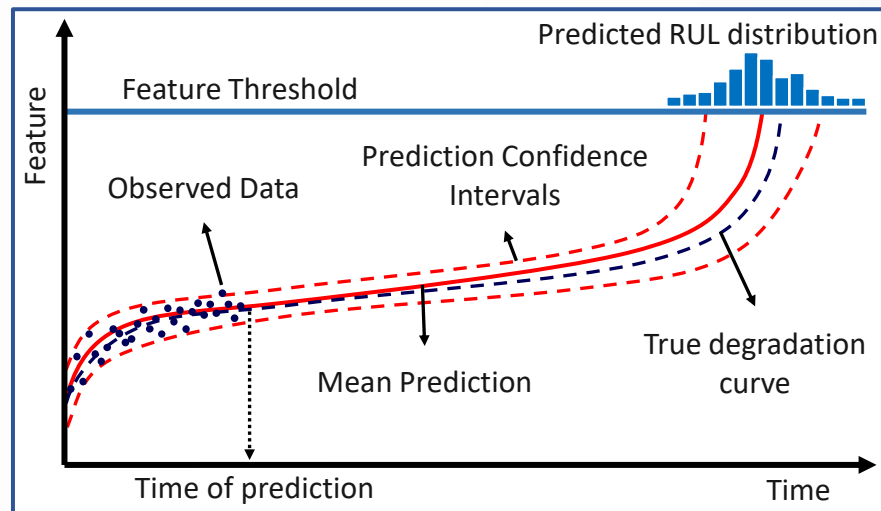
WATER JET: LE SFIDE

- Variabilità del regime operativo



- Modellazione strutturale
- Sensorizzazione "protetta"

APPROCCIO IBRIDO



- Features sensibili al guasto

- Predizione probabilità di guasto

L'operatore virtuale:

sistema di ispezione delle superfici lavorate ed inferenza sul processo

SISTEMA DI ISPEZIONE ROBOTIZZATO

Descrizione Sistema

Robot Arm ABB

Telecamera AVT Prosilica GT2300 + ottica

Sistema di illuminazione (4 x LED Bar CCS + 1 x LED Ring CCS)

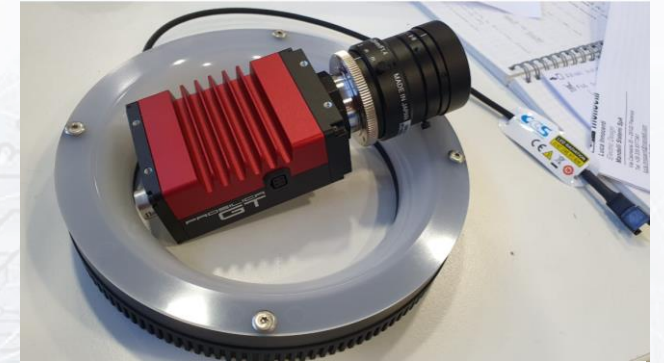
High performance PC

Quadro elettrico con PLC Omron CP1L-M60DT1-D

Gripper



Robot ABB



Camera Prosilica



OBBIETTIVI:

- Formalizzazione della conoscenza dell'operatore (processo, diagnostica, comportamento della macchina, ...)
- Classificazione di immagini e dati di processo tramite machine learning

ANALISI FIRMA TECNOLOGICA: SFIDE E FINALITÀ

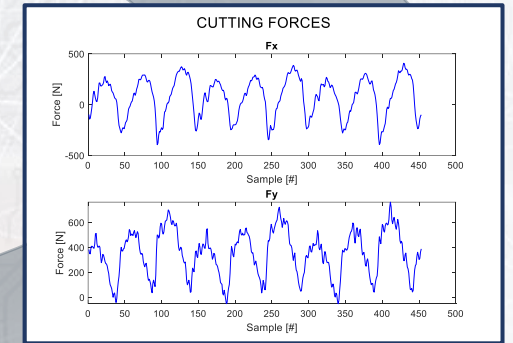
- Acquisizione immagini



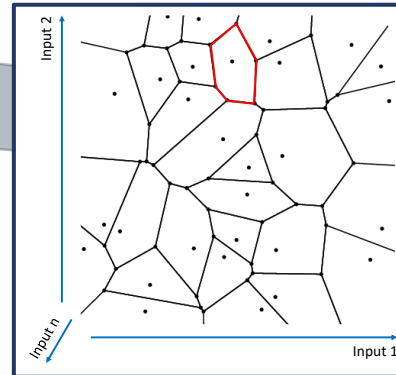
- Variabilità del regime operativo



- Acquisizione features sensori



- Intelligenza Artificiale



SFIDE:

- Gestione di nuove geometrie utensili
- Gestione di nuove condizioni operative

FINALITÀ:

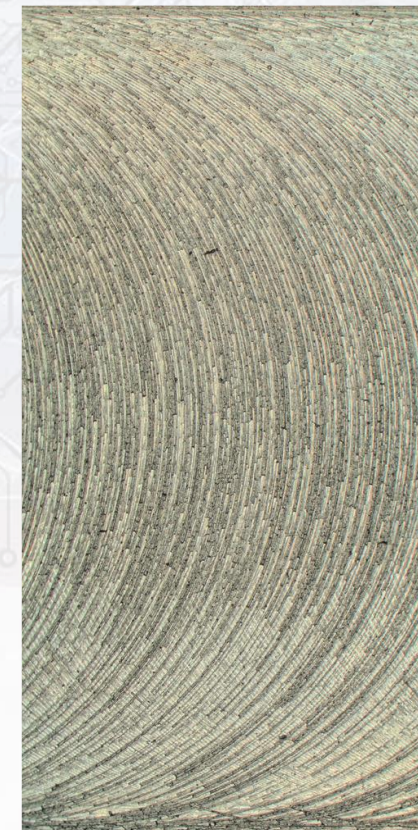
- Inferenza sul processo
- Diagnosi del guasto all'utensile

ANALISI FIRMA TECNOLOGICA: LA SPERIMENTAZIONE

Tipo di parametro	Parametro	Valore
Processo	Condizione utensile	Nominale
		Scheggiatura
	Avanzamento [mm/min]	Run-out
		0.10
		0.15
		0.20
0.60		
Velocità di taglio [m/min]	0.70	
	0.80	
	80	
Tecnologico	Diametro utensile [mm]	150
		220
	Raggio di punta [mm]	27.9
		32.0
		0.4
		0.8
		1.0
1.2		
1.5		

Dataset di 100 test:

- Immagini superficiali
- Misure accelerometriche + forze di taglio



ANALISI FIRMA TECNOLOGICA: LA SPERIMENTAZIONE

Effetti indesiderati

Run-out

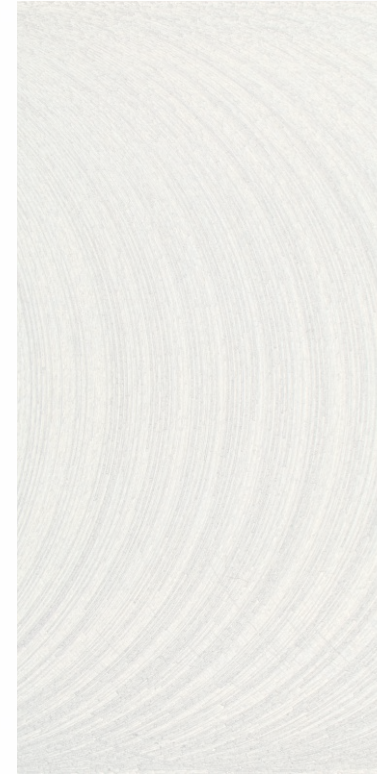


Scheggiatura



Processo: velocità di taglio

Bassa

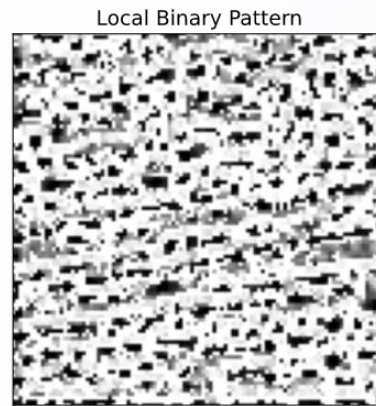
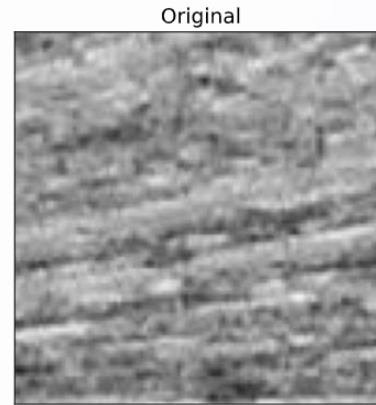
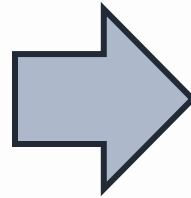
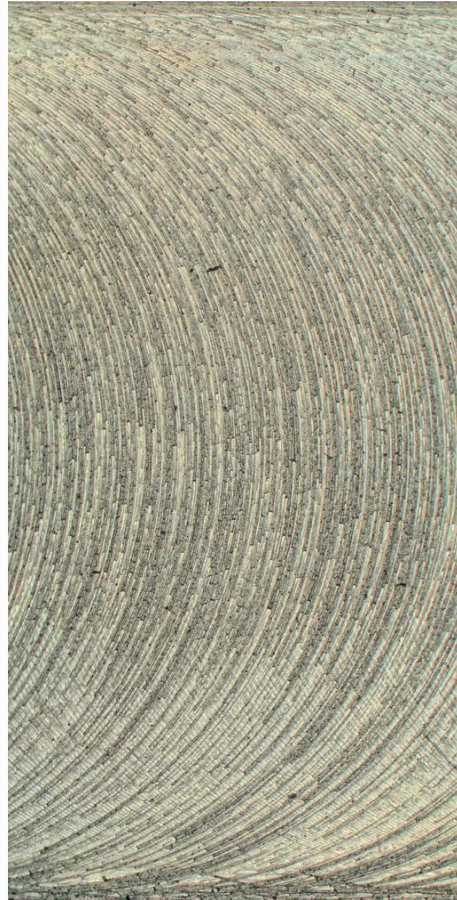


Alta



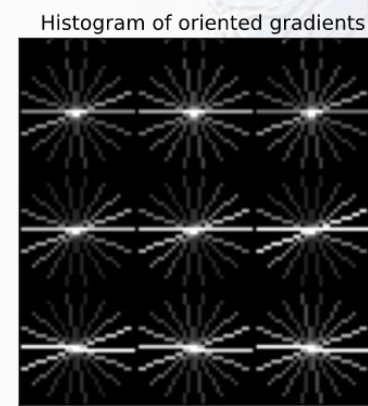
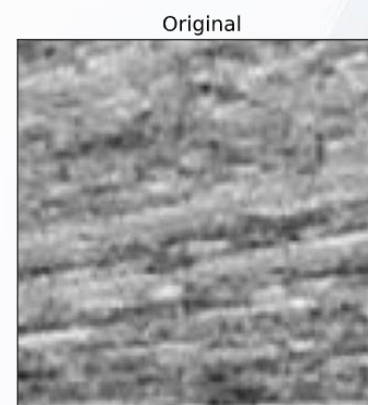
ANALISI FIRMA TECNOLOGICA: STATE OF ART

LBP: local binary patterns



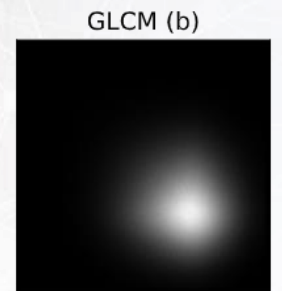
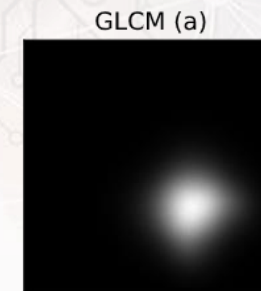
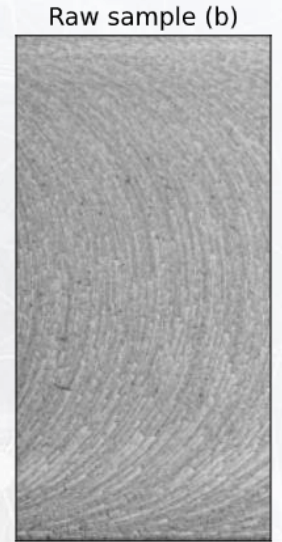
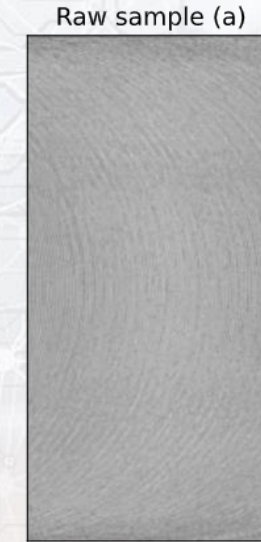
Evidenzia texture

HOG: histogram of oriented gradients



Identifica bordi e relativo orientamento

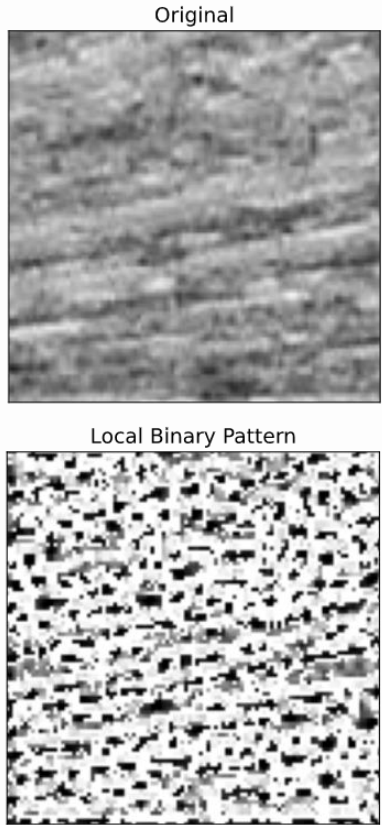
GLCM: Gray – level co-occurrence matrix



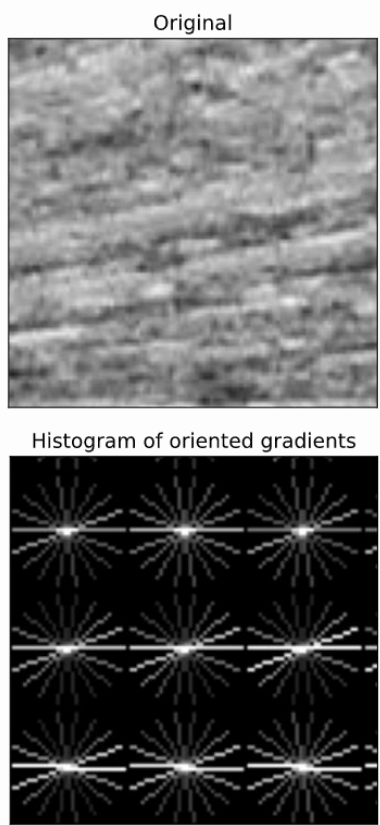
Identifica pattern nelle texture in un immagine

ANALISI FIRMA TECNOLOGICA: STATE OF ART

LBP: local binary patterns

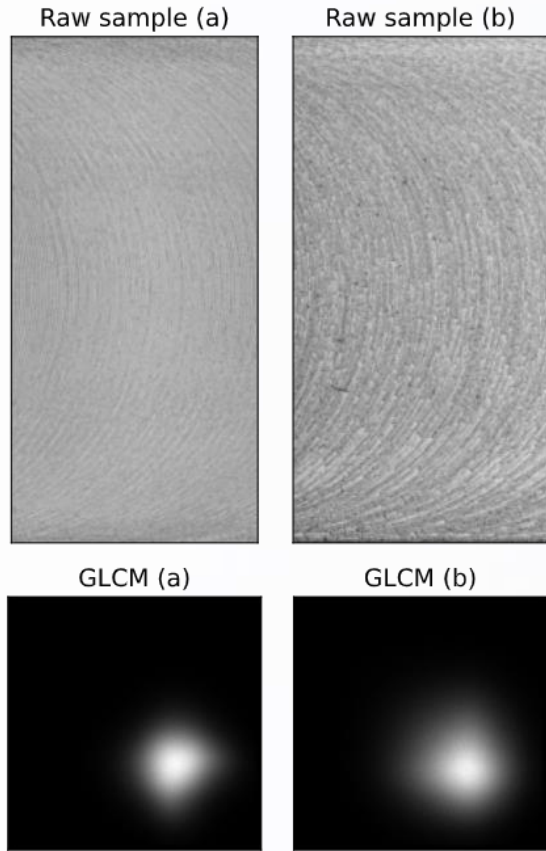


HOG: histogram of oriented gradients



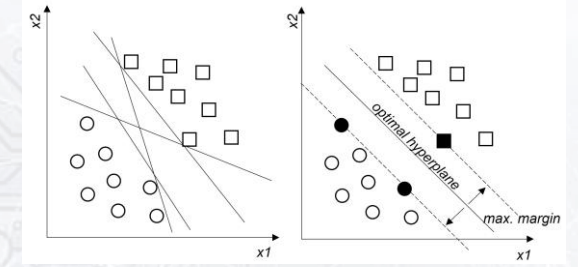
Identifica bordi e relativo orientamento

GLCM: Gray – level co-occurrence matrix

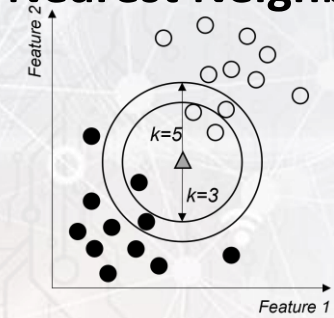


Identifica pattern nelle texture in un immagine

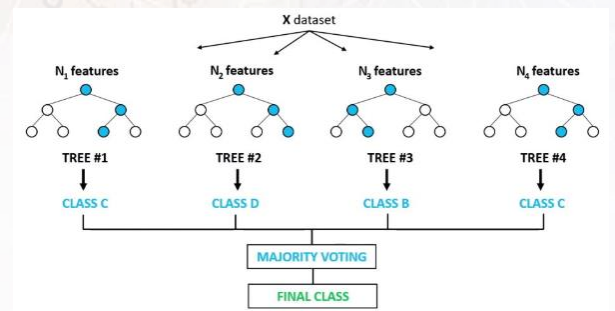
Support Vector Machine



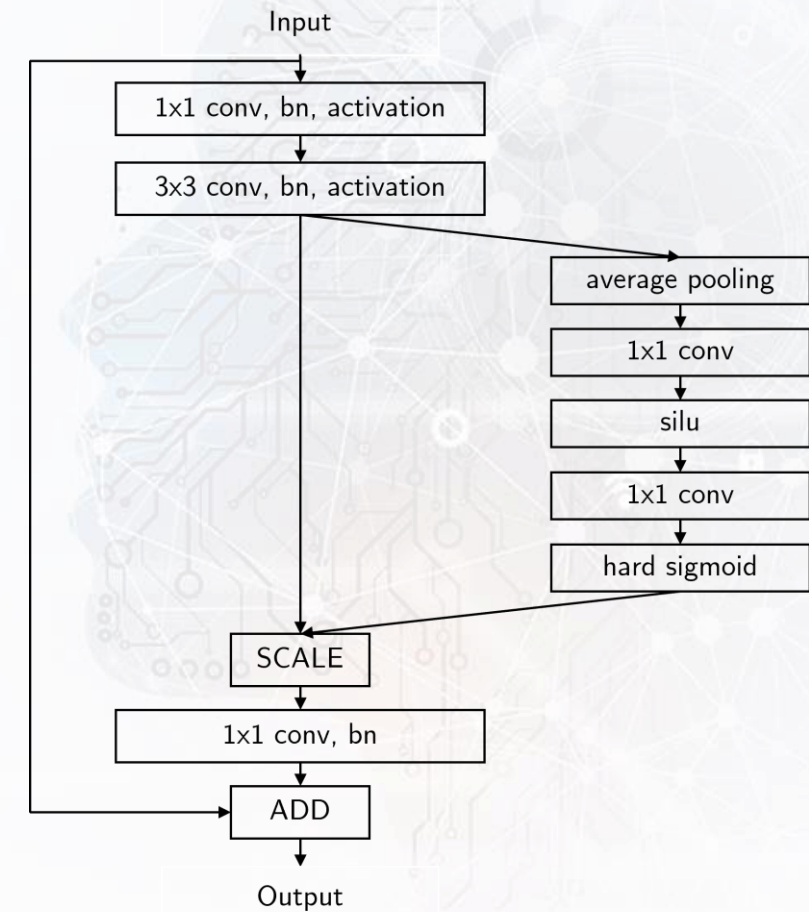
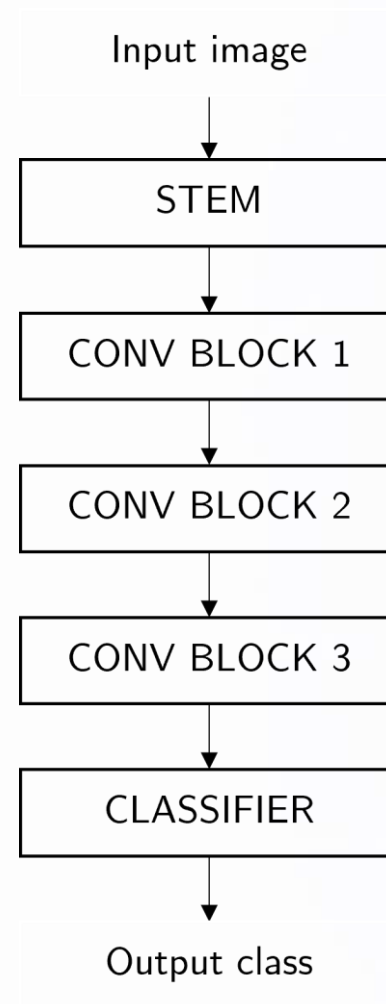
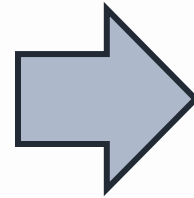
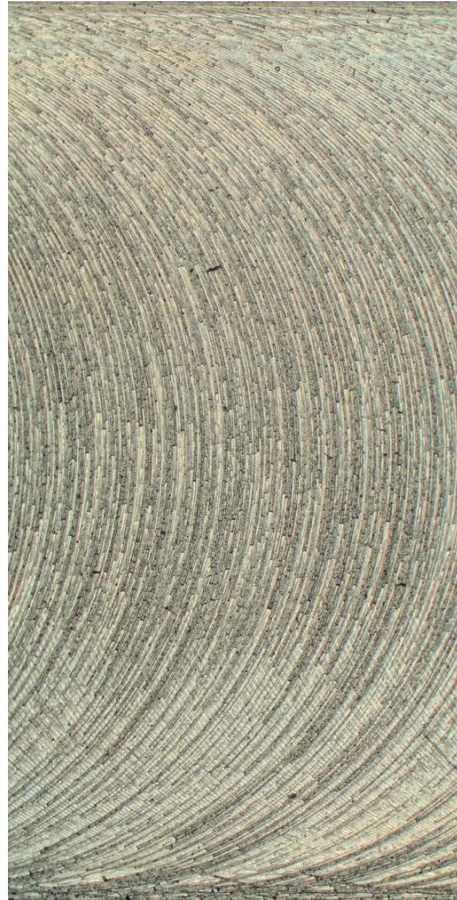
K-Nearest Neighbours



Random Forest Classifier



ANALISI FIRMA TECNOLOGICA: RETE CONVOLUZIONALE



ANALISI FIRMA TECNOLOGICA: RISULTATI

Prestazioni medie

	ML algorithm	Texture descriptor	Global F1-score	score (5-fold)
ML algori	SVM	LBP	0.48836 ± 0.27908	567 ± 0.05590
		HOG	0.74735 ± 0.19355	412 ± 0.07682
		GLCM	0.45527 ± 0.27900	536 ± 0.08090
SVM	KNN	LBP	0.70674 ± 0.20472	429 ± 0.06268
		HOG	0.75930 ± 0.17571	750 ± 0.11087
		GLCM	0.63152 ± 0.18542	167 ± 0.11583
KNN	RF	LBP	0.69601 ± 0.20383	167 ± 0.07360
		HOG	0.73327 ± 0.20770	750 ± 0.09910
		GLCM	0.60355 ± 0.20057	375 ± 0.08210
RF	CNN	LBP	0.69601 ± 0.20383	750 ± 0.09910
		HOG	0.73327 ± 0.20770	375 ± 0.08210
		GLCM	0.60355 ± 0.20057	375 ± 0.08210
	CNN		0.81455 ± 0.12996	

Metrica:

$$F_{1,score} = \frac{2 \cdot P \cdot R}{P + R}$$

Dove:

$$P = \frac{\text{true pos.}}{\text{true pos.} + \text{false pos.}}$$

$$R = \frac{\text{true pos.}}{\text{true pos.} + \text{false neg.}}$$



GRAZIE PER L'ATTENZIONE

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