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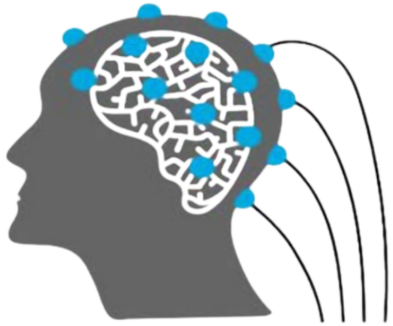

Eeg for human recognition

Progetto Fondamenti di Visione Artificiale e Biometria
a.a. 2022/23

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Simone Masullo

Programma

- Introduzione
- Descrizione progetto
- Stato dell'arte
- Metodo proposto
- Sperimentazione
- Risulati ottenuti
- Conclusioni

Introduzione

Introduzione alla biometria cognitiva

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Introduzione

Cos'è la biometria cognitiva?

Integra le tradizionali modalità biometriche basate su caratteristiche fisiologiche e comportamentali con ulteriori elementi legati "al modo in cui pensiamo, sentiamo e reagiamo".

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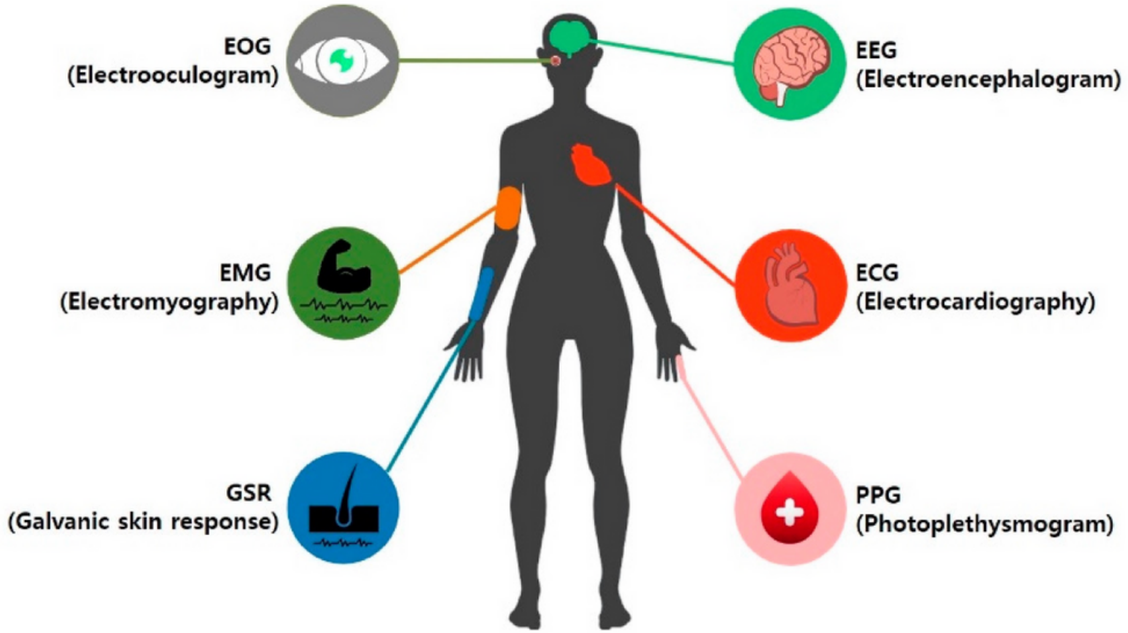
Introduzione

Essa si basa sui segnali provenienti dal cervello, dal cuore e dal sistema nervoso autonomo poiché questi trasmettono informazioni sul processo cognitivo ed emotivo di un individuo.



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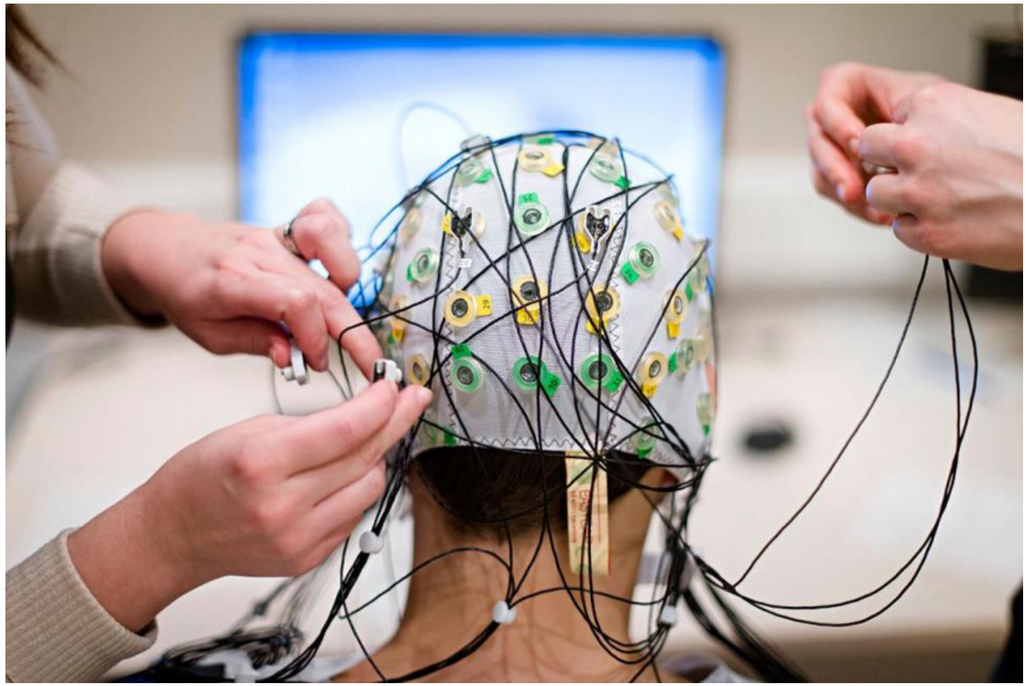
Introduzione

La biometria cognitiva rivela un elevato grado di conformità alla **privacy**, robustezza e protezione degli utenti. La tecnologia di rilevamento attuale impedisce che tali biosegnali possano essere catturati senza il coinvolgimento consapevole dell'utente.



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Introduzione

Campi di applicazione

Sicurezza

Interazione uomo-macchina

Sanità

Task

Identificazione
Autenticazione

Emotion recognition

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Descrizione del progetto

Descrizione dell'obiettivo preposto

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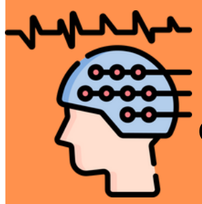
Descrizione progetto

Biosignal acquisition



Signal elicitation protocol

Signal pre-processing

Filtering

De-noising

Segmentation

Artifact removal

Features extraction

Feature selection/ extraction

Classification

ML

DL

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Descrizione progetto

Obiettivo

L'idea del progetto è stata quella di risolvere un'istanza del comune problema di **human identification** basandosi sui segnali EEG relativi ad ogni singolo soggetto. Per farlo vengono esaminate diverse tecniche di preprocessing note ed adoperati algoritmi di machine learning e deep learning.

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Descrizione progetto

BED (Biometric EEG Dataset)

Il dataset comprende le risposte EEG di 21 soggetti a 12 stimoli diversi, suddivisi in 3 sessioni cronologicamente distinte. Sono stati inoltre considerati stimoli mirati a suscitare diversi stati affettivi, al fine di facilitare future ricerche sull'influenza delle emozioni per task biometrici basati su EEG.

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Stato dell'arte

Descrizione dello stato dell'arte e dei lavori correlati

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Stato dell'arte

BED: A New Data Set for EEG-Based Biometrics, 2021

Representation Learning and Pattern Recognition in Cognitive Biometrics: A Survey, 2022

The PREP pipeline: standardized preprocessing for large-scale EEG analysis, 2015

State-of-the-art methods and future perspectives for personal recognition based on electroencephalogram signals, 2015

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Stato dell'arte

A novel deep learning approach for classification of eeg motor imagery signals, 2016	90%
Human identification from brain eeg signals using advanced machine learning method eeg-based biometrics, 2016	94.4%
Human identification with electroencephalogram (eeg) signal processing, 2012	95.1%
Support vector machine approach for human identification based on eeg signals, 2020	99.1%

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Metodo proposto

Approfondimento del metodo e sulle tecniche utilizzate per lo svolgimento del progetto

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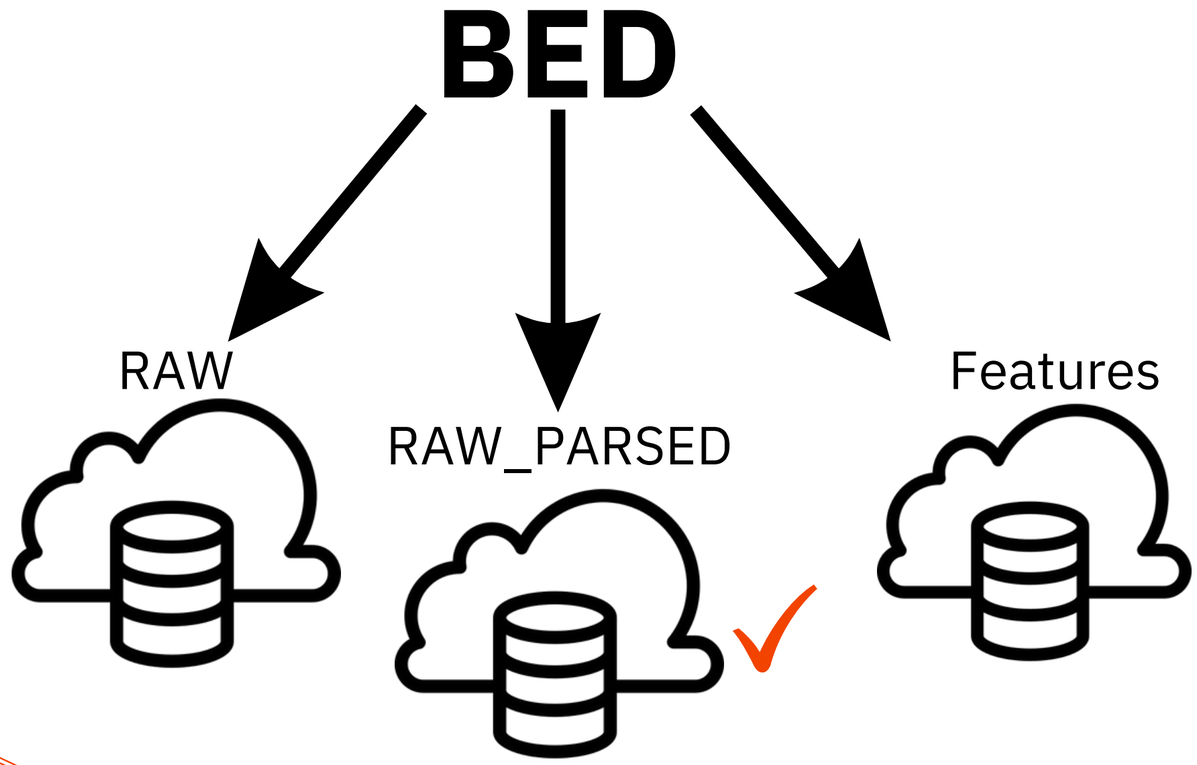
Metodo proposto



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Metodo proposto

Tecniche di pre-processing utilizzate

Filtro passa-banda → 1. eliminare la frequenza del segnale elettrico proveniente dai dispositivi stessi (50Hz);
2. eliminare le frequenze poco significative

Principal Component Analysis → ridurre la numerosità delle informazioni

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Metodo proposto

Altre tecniche di feature extraction

Power Spectral Density

Wavelet Transform

Ottenere valori statistici come ampiezza del segnale, entropia, centroidi...

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Metodo proposto

Scelta del modello

Random Forest → algoritmo di machine learning comunemente utilizzato che combina l'output di più strutture ad albero decisionali per raggiungere un unico risultato

Grid Search → effettua analisi su ogni possibile combinazione dei parametri assegnati in fase di inizializzazione e restituisce la combinazione che raggiunge le performance migliori

Xgboost → basato su un insieme di algoritmi di apprendimento ad albero decisionale, è un modello sequenziale, il che significa che ogni albero successivo dipende dal risultato dell'ultimo.

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Sperimentazione

Implementazione delle tecniche di preprocessing e dei modelli utilizzati

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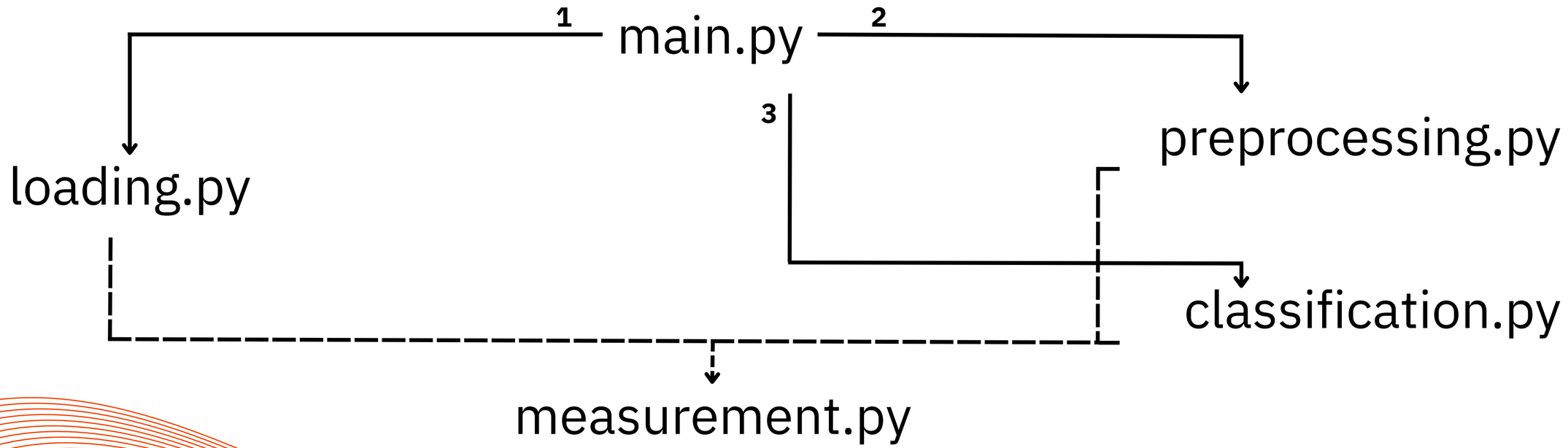
Sperimentazione



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Eeg for human recognition

Sperimentazione

main.py

```python
import loading
import preprocessing
import classification

if __name__ == '__main__':
    # Loading the measurements for different users
    users_measurements = loading.load(loading.PATH_TO_DS_2)

    print("## INFO: starting preprocessing...")

    print("## INFO: applying butterworth bandpass filter...")

    # Apply a butterworth bandpass filter
    new_users_measurements = []
    for user_measurements in users_measurements:
        new_user_measurements = preprocessing.bandpass_filter(user_measurements)
        new_users_measurements.append(new_user_measurements)

    users_measurements = new_users_measurements

    print("## INFO: butterworth bandpass filter applied successfully!")

    # Apply principal component analysis to reduce the complexity of the signal

    print("## INFO: applying Principal Component Analysis...")

    pca_values = []
    for user_measurements in users_measurements:
        current_user_pca_values = preprocessing.pca_processing(user_measurements)
        pca_values.append(current_user_pca_values)

    # Reduce the number of measurements
    users_measurements = pca_values

    print("## INFO: Principal Component Analysis applied successfully!")

    # Starting Classification
    print("## INFO: starting classification...")

    """ TEST TEST TEST"""
    # x_train, y_train, x_test, y_test = classification.train_test_split_session(users_measurements, 2)

    # Split data in train and test
    x_train, y_train, x_test, y_test = classification.train_test_split(users_measurements, perc_train=70)

    # Compute a model for machine learning
    model = classification.classification_by_lstm(x_train, y_train)

    # Make predictions using the computed model
    predictions = classification.prediction_by_lstm(model, x_test)

    # Compute the confusion matrix based on the predictions
    confusion_matrix = classification.compute_confusion_matrix(predictions, y_test)

    # Compute the metrics
    metrics = classification.compute_metrics(confusion_matrix)

    # Print output
    for k, v in metrics.items():
        print("=====\n\tUser ID: {0}\n=====".format(k))
        print("Accuracy: {0}%\nPrecision: {1}%\nRecall: {2}%\nF-Score: {3}".format(*[metric for metric in v]))
```

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Sperimentazione

Librerie utilizzate

Tensorflow

Keras

Scikit-learn

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Sperimentazione

Tecniche di divisione del dataset → Split randomico e split per sessioni

---

Matrice di confusione → Computazione della matrice di confusione e delle metriche di valutazione del modello

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Eeg for human recognition

Sperimentazione

```python
def compute_metrics(confusion_matrix):
    """
    Calculates accuracy, precision, recall and fscore for each class c
    :param confusion_matrix: the confusion matrix previously computed
    :return: a dictionary of key, values where keys are the classes ar
    """

    # Identify all the classes
    classes = set()
    for k in confusion_matrix.keys():
        _, c = k
        classes.add(c)

    # Create a dictionary in which keys are the classes and values are
    metrics = dict()

    for cl in classes:
        # For each class we are computing TP, TN, FP, FN
        tp = tn = fp = fn = 0
        for k, v in confusion_matrix.items():
            p, c = k
            if p == c:
                tp += v
            elif p == cl and c != cl:
                fp += v
            elif p != cl and c == cl:
                fn += v
            elif p != cl and c != cl:
                tn += v

        if tp == tp == fp == fn == 0:
            acc = pr = recall = fscore = 0
        else:
            acc = ((tp + tn) / (tp + tn + fp + fn)) * 100
            pr = (tp / (tp + fp)) * 100
            recall = (tp / (tp + fn)) * 100
            fscore = (2 * recall * pr) / (recall + pr) / 100

        metrics[cl] = (acc, pr, recall, fscore)

    return metrics
```

```python
def compute_confusion_matrix(predictions, correct_labels):
    """
    Computes the confusion matrix given the predictions and
    :param predictions: the predictions of a model
    :param correct_labels: the expected predictions
    :return: a dictionary containing keys as couples (p, c)
    """

    # Create a dictionary for which the key is the tuple (p,
    # is the number of times the model predicted p and the e
    # If p == c then the model predicted the correct value.
    confusion_matrix = dict()

    for i in range(len(predictions)):
        p = predictions[i].item()
        c = correct_labels[i].item()

        key = (p, c)

        if not key in confusion_matrix.keys():
            confusion_matrix[key] = 0
        else:
            confusion_matrix[key] += 1

    return confusion_matrix
```

Eeg for human recognition

Sperimentazione

Random split

```
# Create lists of tuples (m, i) where m is a numpy array and i is the id of the su
train_data = []
test_data = []

# For each subject split into train and test
for user_measurement in users_measurements:
    # Calculate the number of measurements to use for training
    training_dataset_length = math.ceil(len(user_measurement) * perc_train / 100)

    # Get the measurement values
    data_set = user_measurement.values

    # Shuffle the measurement values
    np.random.shuffle(data_set)

    # Get the training portion
    train_data_0 = data_set[0:training_dataset_length]
    train_data.append((train_data_0, user_measurement.subject_id))

    # Get the testing portion
    test_data_0 = data_set[training_dataset_length:]
    test_data.append((test_data_0, user_measurement.subject_id))
```

Session split

```
# Create lists of tuples (m, i) where m is a numpy array and i is the id of the subject (source of
train_data = []
test_data = []

# For each user extract the rows of each session
for user_measurement in users_measurements:
    first_session_rows = user_measurement.sessions[1]
    second_session_rows = user_measurement.sessions[2]

    # Split data into three list of values containing each session
    first_session_measurements = user_measurement.values[:first_session_rows]
    second_session_measurements = user_measurement.values[first_session_rows:second_session_rows]
    third_session_measurements = user_measurement.values[second_session_rows:]

    user_session_measurements = [first_session_measurements, second_session_measurements,
                                 third_session_measurements]

    # Gather train data
    for i in range(n_session_train):
        train_data_0 = (user_session_measurements[i], user_measurement.subject_id)
        train_data.append(train_data_0)

    # Gather test data
    for i in range(n_session_train, len(user_session_measurements)):
        test_data_0 = (user_session_measurements[i], user_measurement.subject_id)
        test_data.append(test_data_0)
```

Eeg for human recognition

Sperimentazione

gridsearch

```python
def classification_by_gridsearch(x_train, y_train):
    """
    Trains a model using the random forest algorithm and the gridsearch tecnique to compute the best params.
    :param x_train: the measurements for the train
    :param y_train: the labels for the training
    :return: the trained model
    """
    param_grid = {
        'n_estimators': [10, 50, 100],
        'max_depth': [None, 5, 10],
        'criterion': ['gini', 'entropy']
    }

    rfc = RandomForestClassifier()
    grid_search = GridSearchCV(estimator=rfc, param_grid=param_grid, cv=5)
    grid_search.fit(x_train, y_train)
    print("#### GridSearch output ####")
    print("Migliori parametri:", grid_search.best_params_)
    print("Miglior punteggio di validazione incrociata:", grid_search.best_score_)
    print("Miglior modello trovato:", grid_search.best_estimator_)

    return grid_search
```

```
/Users/mattiadargenio/PycharmProjects/provaEEG/venv/bin/python /Users/mattiadargenio/PycharmProjects/provaEEG/
## INFO: loading 937363 measurements for subject 1
## INFO: loading 828630 measurements for subject 2
## INFO: loading 873457 measurements for subject 3
## INFO: loading 3 subjects
## INFO: starting preprocessing...
## INFO: applying butterworth bandpass filter...
## INFO: butterworth bandpass filter applied successfully!
## INFO: applying Principal Component Analysis...
## INFO: Principal Component Analysis applied successfully!
## INFO: starting classification...
Migliori parametri: {'criterion': 'gini', 'max_depth': None, 'n_estimators': 100}
Miglior punteggio di validazione incrociata: 0.9998695616548678
Miglior modello trovato: RandomForestClassifier()

Process finished with exit code 0
```

Risultati ottenuti

Comparazioni dei risultati ottenuti nei vari modelli

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Eeg for human recognition

Risultati ottenuti

tensorflow_decision_forests

```
/Users/mattiadargenio/PycharmProjects/provaEEG/venv/bin/python /Users/ma                    /python-project/main.py
## INFO: loading 937363 measurements for subject 1
## INFO: loading 828630 measurements for subject 2
## INFO: loading 873457 measurements for subject 3
## INFO: loading 881930 measurements for subject 4
## INFO: loading 970655 measurements for subject 5
## INFO: loading 933960 measurements for subject 6
## INFO: loading 1080314 measurements for subject 7
## INFO: loading 884098 measurements for subject 8
## INFO: loading 1071813 measurements for subject 9
## INFO: loading 1090372 measurements for subject 10
## INFO: loading 1331210 measurements for subject 11
## INFO: loading 867922 measurements for subject 12
## INFO: loading 877334 measurements for subject 13
## INFO: loading 890254 measurements for subject 14
## INFO: loading 848005 measurements for subject 15
## INFO: loading 941757 measurements for subject 16
## INFO: loading 945612 measurements for subject 17
## INFO: loading 877143 measurements for subject 18
## INFO: loading 761855 measurements for subject 19
## INFO: loading 940829 measurements for subject 20
## INFO: loading 849249 measurements for subject 21
## INFO: loading 21 subjects
## INFO: starting preprocessing...
## INFO: applying butterworth bandpass filter...
## INFO: butterworth bandpass filter applied successfully!
## INFO: applying Principal Component Analysis...
## INFO: Principal Component Analysis applied successfully!
## INFO: starting classification...
Use /var/folders/c5/lnjb3v793d91yp_vjy4yk0jh0000gn/T/tmprmw1wmd6 as tem
Reading training dataset...
2023-06-12 15:53:47.920759: W tensorflow/tsl/platform/profile_utils/cpu_utils.cc:128] Failed to get CPU frequency: 0 Hz
Training dataset read in 0:00:17.976269. Found 13778642 examples.
Training model...
[INFO 23-06-12 17:29:29.1491 CEST kernel.cc:1242] Loading model from path /var/folders/c5/lnjb3v793d91yp_vjy4yk0jh0000gn/T/tmprmw1wmd6/model/ with prefix d0d0899d8c1b47e7
[INFO 23-06-12 17:29:31.9894 CEST decision_forest.cc:660] Model loaded with 300 root(s), 2069978 node(s), and 13 input feature(s).
[INFO 23-06-12 17:29:31.9894 CEST abstract_model.cc:1312] Engine "RandomForestGeneric" built
[INFO 23-06-12 17:29:31.9894 CEST kernel.cc:1074] Use fast generic engine
Model trained in 1:35:26.738192
```

Eeg for human recognition

Risultati ottenuti

```
Model trained in 1:35:26.738192
Compiling model...
WARNING:tensorflow:AutoGraph could not transform <function simple_ml_inf
Please report this to the TensorFlow team. When filing the bug, set the
Cause: could not get source code
To silence this warning, decorate the function with @tf.autograph.experi
WARNING:tensorflow:AutoGraph could not transform <function simple_ml_inf
Please report this to the TensorFlow team. When filing the bug, set the
Cause: could not get source code
To silence this warning, decorate the function with @tf.autograph.experi
Model compiled.

## INFO: starting predictions
184535/184535 [==============================] - 329s 2ms/step
 =====
 Class 1
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 2
=====
Accuracy: 99.89
Precision: 99.99
Recall: 99.89
F-Score: 99.94
 =====
 Class 3
=====
Accuracy: 99.75
Precision: 100.0
Recall: 99.75
F-Score: 99.87
 =====
 Class 4
=====
Accuracy: 99.94
Precision: 100.0
Recall: 99.94
F-Score: 99.97
 =====
 Class 5
=====
Accuracy: 99.98
Precision: 100.0
Recall: 99.98
F-Score: 99.99
 =====
 Class 6
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 7
=====
Accuracy: 99.95
Precision: 99.96
Recall: 99.98
F-Score: 99.97
 =====
 Class 8
=====
Accuracy: 99.99
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 9
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 10
=====
Accuracy: 99.97
Precision: 100.0
Recall: 99.97
F-Score: 99.98
 =====
 Class 11
=====
Accuracy: 99.98
Precision: 100.0
Recall: 99.98
F-Score: 99.99
 =====
 Class 12
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 13
=====
Accuracy: 99.99
Precision: 100.0
Recall: 99.99
F-Score: 99.99
 =====
 Class 14
=====
Accuracy: 99.99
Precision: 100.0
Recall: 99.99
F-Score: 99.99
 =====
 Class 15
=====
Accuracy: 99.98
Precision: 99.99
Recall: 99.99
F-Score: 99.99
 =====
 Class 16
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 17
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 18
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 18
=====
Accuracy: 100.0
Precision: 100.0
Recall: 100.0
F-Score: 100.0
 =====
 Class 19
=====
Accuracy: 99.91
Precision: 100.0
Recall: 99.92
F-Score: 99.96
 =====
 Class 20
=====
Accuracy: 99.98
Precision: 100.0
Recall: 99.98
F-Score: 99.99
 =====
 Class 21
=====
Accuracy: 99.95
Precision: 99.95
Recall: 100.0
F-Score: 99.97

Process finished with exit code 0
```

Eeg for human recognition

Risultati ottenuti

tensorflow_decision_forests con session split

```
=====
    User ID: 1
=====
Accuracy: 99.9974353779769%
Precision: 99.95806204403787%
Recall: 99.99396359443806%
F-Score: 0.9997600959616154
=====
    User ID: 2
=====
Accuracy: 99.88891476809366%
Precision: 99.53626814485689%
Recall: 97.54303493523622%
F-Score: 0.9852957189554346
=====
    User ID: 3
=====
Accuracy: 99.76518385275263%
Precision: 99.93455920024455%
Recall: 94.15637359294189%
F-Score: 0.9695945663706464
=====
    User ID: 4
=====
Accuracy: 99.94252988510493%
Precision: 99.96532920298621%
Recall: 98.70837860768349%
F-Score: 0.9933287772545569
=====
    User ID: 5
=====
Accuracy: 99.99306422974884%
Precision: 99.98975590801513%
Recall: 99.85853483006541%
F-Score: 0.9992410228893377
=====
=====
    User ID: 6
=====
Accuracy: 99.99549981418588%
Precision: 99.96503310199678%
Recall: 99.94206816645746%
F-Score: 0.9995354931514374
=====
    User ID: 7
=====
Accuracy: 99.9072058459188%
Precision: 99.31041939475487%
Recall: 98.96533250328477%
F-Score: 0.9913757564764276
=====
    User ID: 8
=====
Accuracy: 99.98556392005864%
Precision: 99.88638837487754%
Recall: 99.80932052166642%
F-Score: 0.9984783957701101
=====
    User ID: 9
=====
Accuracy: 99.99777410164032%
Precision: 100.0%
Recall: 99.95777156251339%
F-Score: 0.9997888132221288
=====
    User ID: 10
=====
Accuracy: 99.96340171465144%
Precision: 99.9775418991656%
Recall: 99.46524064171123%
F-Score: 0.9972073330584565
=====
=====
    User ID: 11
=====
Accuracy: 99.98728979777229%
Precision: 99.96193537472509%
Recall: 99.81614852271255%
F-Score: 0.9988898875518076
=====
    User ID: 12
=====
Accuracy: 99.99975805452613%
Precision: 100.0%
Recall: 99.99466186471741%
F-Score: 0.999973308611176
=====
    User ID: 13
=====
Accuracy: 99.98880598940859%
Precision: 99.96893123446561%
Recall: 99.7836346526748%
F-Score: 0.9987619700018553
=====
    User ID: 14
=====
Accuracy: 99.98651557225588%
Precision: 99.9996487740458%
Recall: 99.70758288361799%
F-Score: 0.9985340225999003
=====
    User ID: 15
=====
Accuracy: 99.97245047537446%
Precision: 99.73936879861775%
Recall: 99.63839890463636%
F-Score: 0.9968885828478576
=====
=====
    User ID: 16
=====
Accuracy: 99.99959675754354%
Precision: 99.99666859887931%
Recall: 99.99500298155434%
F-Score: 0.9999583578328083
=====
    User ID: 17
=====
Accuracy: 99.99491914504857%
Precision: 99.9826011891418%
Recall: 99.91206424993815%
F-Score: 0.9994732027433594
=====
    User ID: 18
=====
Accuracy: 99.9989515696132%
Precision: 99.98807333812809%
Recall: 99.98843471032563%
F-Score: 0.9998825402390036
=====
    User ID: 19
=====
Accuracy: 99.89754415666195%
Precision: 99.92551178902907%
Recall: 97.45087275413883%
F-Score: 0.9867267917368429
=====
    User ID: 20
=====
Accuracy: 99.98053145420198%
Precision: 99.95318449470464%
Recall: 99.62945424001826%
F-Score: 0.9979105681627369
=====
=====
    User ID: 21
=====
Accuracy: 99.91199636630158%
Precision: 99.24374881506604%
Recall: 98.8453495772343%
F-Score: 0.9904414856341976

Process finished with exit code 0
```

Risultati ottenuti

Grid Search

```
/Users/mattiadargenio/PycharmProjects/provaEEG/venv/bin/python /Users/mattiadargenio/
## INFO: loading 937363 measurements for subject 1
## INFO: loading 828630 measurements for subject 2
## INFO: loading 873457 measurements for subject 3
## INFO: loading 3 subjects
## INFO: starting preprocessing...
## INFO: applying butterworth bandpass filter...
## INFO: butterworth bandpass filter applied successfully!
## INFO: applying Principal Component Analysis...
## INFO: Principal Component Analysis applied successfully!
## INFO: starting classification...
Migliori parametri: {'criterion': 'gini', 'max_depth': None, 'n_estimators': 100}
Miglior punteggio di validazione incrociata: 0.9998695616548678
Miglior modello trovato: RandomForestClassifier()


Process finished with exit code 0
```

Eeg for human recognition

RandomForestClassifier

Risultati ottenuti

```
/Users/mattiadargenio/PycharmProjects/provaEEG/venv/bin/python
## INFO: loading 937363 measurements for subject 1
## INFO: loading 828630 measurements for subject 2
## INFO: loading 873457 measurements for subject 3
## INFO: loading 881930 measurements for subject 4
## INFO: loading 970655 measurements for subject 5
## INFO: loading 933960 measurements for subject 6
## INFO: loading 1080314 measurements for subject 7
## INFO: loading 884098 measurements for subject 8
## INFO: loading 1071813 measurements for subject 9
## INFO: loading 1090372 measurements for subject 10
## INFO: loading 1331210 measurements for subject 11
## INFO: loading 867922 measurements for subject 12
## INFO: loading 877334 measurements for subject 13
## INFO: loading 890254 measurements for subject 14
## INFO: loading 848005 measurements for subject 15
## INFO: loading 941757 measurements for subject 16
## INFO: loading 945612 measurements for subject 17
## INFO: loading 877143 measurements for subject 18
## INFO: loading 761855 measurements for subject 19
## INFO: loading 940829 measurements for subject 20
## INFO: loading 849249 measurements for subject 21
## INFO: loading 21 subjects
## INFO: starting preprocessing...
## INFO: applying butterworth bandpass filter...
## INFO: butterworth bandpass filter applied successfully!
## INFO: applying Principal Component Analysis...
## INFO: Principal Component Analysis applied successfully!
## INFO: starting classification...

## INFO: starting predictions
=====
    User ID: 1
=====
Accuracy: 99.99981371718883%
Precision: 100.0%
Recall: 99.99981370510568%
F-Score: 0.9999990685246607
=====
=====
    User ID: 2
=====
Accuracy: 99.99744284504656%
Precision: 99.9987975633553%
Recall: 99.99864514387386%
F-Score: 0.9999872135355651
=====
    User ID: 3
=====
Accuracy: 99.99815410668924%
Precision: 99.99850966028045%
Recall: 99.99964434671318%
F-Score: 0.99999077000278
=====
    User ID: 4
=====
Accuracy: 99.9996782387807%
Precision: 99.99989838451705%
Recall: 99.99977983338128%
F-Score: 0.9999983910891403
=====
    User ID: 5
=====
Accuracy: 99.99989839119391%
Precision: 99.9999491922327%
Recall: 99.9999491922327%
F-Score: 0.9999994919223271
=====
    User ID: 6
=====
Accuracy: 99.99996613039797%
Precision: 99.999996612814941%
Recall: 100.0%
F-Score: 0.9999998306407183
=====
=====
    User ID: 7
=====
Accuracy: 99.997900084674%
Precision: 99.99839111243736%
Recall: 99.9995088604122%
F-Score: 0.9999894998330134
=====
    User ID: 8
=====
Accuracy: 99.999593564477561%
Precision: 99.99989838451705%
Recall: 99.9996951541707%
F-Score: 0.9999979676924062
=====
    User ID: 9
=====
Accuracy: 100.0%
Precision: 100.0%
Recall: 100.0%
F-Score: 1.0
=====
    User ID: 10
=====
Accuracy: 99.99974597798476%
Precision: 99.99979676924062%
Recall: 99.9999491922327%
F-Score: 0.9999987298067857
=====
    User ID: 11
=====
Accuracy: 99.99984758679086%
Precision: 99.99991532041653%
Recall: 99.99993225632176%
F-Score: 0.9999992378836844
=====
=====
    User ID: 12
=====
Accuracy: 100.0%
Precision: 100.0%
Recall: 100.0%
F-Score: 1.0
=====
    User ID: 13
=====
Accuracy: 99.99989839119391%
Precision: 99.99989838451705%
Recall: 100.0%
F-Score: 0.9999994919223272
=====
    User ID: 14
=====
Accuracy: 99.99993226079593%
Precision: 100.0%
Recall: 99.99993225632176%
F-Score: 0.999999661281494
=====
    User ID: 15
=====
Accuracy: 99.99939034716341%
Precision: 99.9994072459274%
Recall: 99.99998306407183%
F-Score: 0.9999969515417071
=====
    User ID: 16
=====
Accuracy: 99.99998306519899%
Precision: 99.99998306407183%
Recall: 100.0%
F-Score: 0.9999999153203518
=====
=====
    User ID: 17
=====
Accuracy: 99.99996613039797%
Precision: 99.99996612814941%
Recall: 100.0%
F-Score: 0.9999998306407183
=====
    User ID: 18
=====
Accuracy: 99.99998306519899%
Precision: 99.99998306407183%
Recall: 100.0%
F-Score: 0.9999999153203518
=====
    User ID: 19
=====
Accuracy: 99.99817104149025%
Precision: 99.99944111739939%
Recall: 99.99872982130617%
F-Score: 0.9999908546808791
=====
    User ID: 20
=====
Accuracy: 99.99932260795936%
Precision: 99.99989838451705%
Recall: 99.99942418166053%
F-Score: 0.9999966128252663
=====
    User ID: 21
=====
Accuracy: 99.99796782387807%
Precision: 99.99962741090548%
Recall: 99.99834030630494%
F-Score: 0.9999898385446356

Process finished with exit code 0
```

Eeg for human recognition

Risultati ottenuti

RandomForestClassifier con session split

```
=====
    User ID: 1
=====
Accuracy: 99.98949956643372%
Precision: 99.80450040666325%
Recall: 99.99939635944381%
F-Score: 0.9990185332877024
=====
    User ID: 2
=====
Accuracy: 99.86128459497682%
Precision: 97.92411258651282%
Recall: 98.45150326355304%
F-Score: 0.9818709973902667
=====
    User ID: 3
=====
Accuracy: 99.79844329056168%
Precision: 99.806756704989%
Recall: 95.11530270763615%
F-Score: 0.9740457190806334
=====
    User ID: 4
=====
Accuracy: 99.9517560725088%
Precision: 99.80508357041919%
Recall: 99.08049655418782%
F-Score: 0.9944147014171457
=====
    User ID: 5
=====
Accuracy: 99.9925319497063%
Precision: 99.94352655487278%
Recall: 99.89310736536115%
F-Score: 0.9991831059968489
=====
=====
    User ID: 6
=====
Accuracy: 99.987128500789 71%
Precision: 99.76343864522109%
Recall: 99.97136702480081%
F-Score: 0.9986729460597472
=====
    User ID: 7
=====
Accuracy: 99.86130072467509%
Precision: 97.990835805228 43%
Recall: 99.46575600762607%
F-Score: 0.9872278738026595
=====
    User ID: 8
=====
Accuracy: 99.95656272258984%
Precision: 99.23658449253136%
Recall: 99.85282671280136%
F-Score: 0.9954375187420901
=====
    User ID: 9
=====
Accuracy: 99.99975805452613%
Precision: 99.99571612603158%
Recall: 99.9996939968298%
F-Score: 0.9999770502187114
=====
    User ID: 10
=====
Accuracy: 99.981531495494%
Precision: 99.86078202688601%
Recall: 99.85808498205192%
F-Score: 0.9985943348625824
=====
=====
    User ID: 11
=====
Accuracy: 99.9821121646313%
Precision: 99.75884312154813%
Recall: 99.92933120857711%
F-Score: 0.9984401438612136
=====
    User ID: 12
=====
Accuracy: 99.99988709211219%
Precision: 99.99928824103006%
Recall: 99.99822062157247%
F-Score: 0.9999875442845171
=====
    User ID: 13
=====
Accuracy: 99.98428967389621%
Precision: 99.78984861976848%
Recall: 99.86312307516825%
F-Score: 0.9982647240127277
=====
    User ID: 14
=====
Accuracy: 99.99056412651878%
Precision: 99.99719280515963%
Recall: 99.79793451957794%
F-Score: 0.9989746430092562
=====
    User ID: 15
=====
Accuracy: 99.96125646478306%
Precision: 99.21284042753214%
Recall: 99.91806621706262%
F-Score: 0.9956420453720771
=====
=====
    User ID: 16
=====
Accuracy: 99.99846767866543%
Precision: 99.96969353839596%
Recall: 99.99866746174783%
F-Score: 0.9998417840101926
=====
    User ID: 17
=====
Accuracy: 99.99406427104087%
Precision: 99.90310530782442%
Recall: 99.97392019579915%
F-Score: 0.9993850020722757
=====
    User ID: 18
=====
Accuracy: 99.99608048332318%
Precision: 99.9183817926392%
Recall: 99.9938559398605%
F-Score: 0.999561046191308
=====
    User ID: 19
=====
Accuracy: 99.91412548647169%
Precision: 99.54543363623817%
Recall: 98.25118974405541%
F-Score: 0.9889407737303909
=====
    User ID: 20
=====
Accuracy: 99.97938624562562%
Precision: 99.70318728537163%
Recall: 99.85551480627576%
F-Score: 0.9977929290835994
=====
=====
    User ID: 21
=====
Accuracy: 99.8582199523077%
Precision: 97.7478656919017%
Recall: 99.21216614097786%
F-Score: 0.9847457274153466

Process finished with exit code 0
```

Eeg for human recognition

Risultati ottenuti

xgboost

```
/Users/mattiadargenio/PycharmProjects/provaEEG/venv/bin/python /l
## INFO: loading 937363 measurements for subject 1
## INFO: loading 828630 measurements for subject 2
## INFO: loading 873457 measurements for subject 3
## INFO: loading 881930 measurements for subject 4
## INFO: loading 970655 measurements for subject 5
## INFO: loading 933960 measurements for subject 6
## INFO: loading 1080314 measurements for subject 7
## INFO: loading 884098 measurements for subject 8
## INFO: loading 1071813 measurements for subject 9
## INFO: loading 1090372 measurements for subject 10
## INFO: loading 1331210 measurements for subject 11
## INFO: loading 867922 measurements for subject 12
## INFO: loading 877334 measurements for subject 13
## INFO: loading 890254 measurements for subject 14
## INFO: loading 848005 measurements for subject 15
## INFO: loading 941757 measurements for subject 16
## INFO: loading 945612 measurements for subject 17
## INFO: loading 877143 measurements for subject 18
## INFO: loading 761855 measurements for subject 19
## INFO: loading 940829 measurements for subject 20
## INFO: loading 849249 measurements for subject 21
## INFO: loading 21 subjects
## INFO: starting preprocessing...
## INFO: applying butterworth bandpass filter...
## INFO: butterworth bandpass filter applied successfully!
## INFO: applying Principal Component Analysis...
## INFO: Principal Component Analysis applied successfully!
## INFO: starting classification...

[10. 17. 20. ... 17. 16. 17.]
=====
    User ID: 1
=====
Accuracy: 99.83279546073463%
Precision: 99.98304768753148%
Recall: 99.82079970886161%
F-Score: 0.9990185782257172
=====
    User ID: 12
=====
Accuracy: 99.76181863261134%
Precision: 99.74039765069699%
Recall: 99.98040189447028%
F-Score: 0.9986025556617859
=====
    User ID: 13
=====
Accuracy: 99.71997092507313%
Precision: 99.78811207461314%
Recall: 99.88341990540017%
F-Score: 0.9983574324369296
=====
    User ID: 14
=====
Accuracy: 99.39545219911312%
Precision: 99.41331435153184%
Recall: 99.87990585668646%
F-Score: 0.9964606390481433
=====
    User ID: 15
=====
Accuracy: 99.29846238888595%
Precision: 99.72905510846826%
Recall: 99.450362305288%
F-Score: 0.9958951373271977
=====
    User ID: 16
=====
Accuracy: 99.2978527096179%
Precision: 99.32047157454326%
Recall: 99.85930302134838%
F-Score: 0.9958915846057101
=====
    User ID: 7
=====
Accuracy: 98.280789141747 72%
Precision: 98.66954473480826%
Recall: 99.33268350462335%
F-Score: 0.9900000364476828
=====
    User ID: 8
=====
Accuracy: 98.70858076150296%
Precision: 99.68351297816986%
Recall: 98.8142123826424%
F-Score: 0.9924695917364299
=====
    User ID: 9
=====
Accuracy: 99.75443473925372%
Precision: 99.75255465236957%
Recall: 99.95951896998754%
F-Score: 0.9985592957122057
=====
    User ID: 10
=====
Accuracy: 99.55791478851582%
Precision: 99.71973358914448%
Recall: 99.76213978501455%
F-Score: 0.9974093217968891
=====
    User ID: 11
=====
Accuracy: 99.62543676745342%
Precision: 99.81387979972116%
Recall: 99.74697077549179%
F-Score: 0.9978041407093369
=====
    User ID: 2
=====
Accuracy: 99.59554554778327%
Precision: 99.89154088477272%
Recall: 99.63465390764274%
F-Score: 0.9976293202714658
=====
    User ID: 3
=====
Accuracy: 99.58690842481 91%
Precision: 99.72761025781068%
Recall: 99.78817152327849%
F-Score: 0.9975788169912413
=====
    User ID: 4
=====
Accuracy: 99.583233413675 52%
Precision: 99.75302990480108%
Recall: 99.75843621995566%
F-Score: 0.9975573298912883
=====
    User ID: 5
=====
Accuracy: 99.00474940149819%
Precision: 99.77788795791746%
Recall: 99.06199828411195%
F-Score: 0.9941865440064086
=====
    User ID: 6
=====
Accuracy: 98.91897091558923%
Precision: 98.86038327840774%
Recall: 99.88260589471064%
F-Score: 0.9936886571627394
=====
    User ID: 17
=====
Accuracy: 94.96796135446345%
Precision: 94.91656332904242%
Recall: 99.44577654216809%
F-Score: 0.9712839795224792
=====
    User ID: 18
=====
Accuracy: 95.2251274568381%
Precision: 99.60013359272256%
Recall: 95.04859384188602%
F-Score: 0.972711485887584
=====
    User ID: 19
=====
Accuracy: 99.12958123163341%
Precision: 99.48288808981593%
Recall: 99.49951359199983%
F-Score: 0.9949120014635571
=====
    User ID: 20
=====
Accuracy: 95.2909389467181%
Precision: 95.43355702403686%
Recall: 99.25702575245056%
F-Score: 0.9730774742256064
=====
    User ID: 21
=====
Accuracy: 95.67966028671184%
Precision: 99.9925975791298%
Recall: 95.17527743769395%
F-Score: 0.9752448465700616

Process finished with exit code 0
```

Eeg for human recognition

Risultati ottenuti

Xgboost con session split

```
=====
    User ID: 1
=====
Accuracy: 99.96033707198234%
Precision: 99.80946437983533%
Recall: 99.44766889108212%
F-Score: 0.9962823817550968
=====
    User ID: 2
=====
Accuracy: 99.33011750162586%
Precision: 93.51379573476846%
Recall: 88.5877101017958%
F-Score: 0.9098412436528938
=====
    User ID: 3
=====
Accuracy: 99.18498247669582%
Precision: 94.96723748692253%
Recall: 83.95254031031335%
F-Score: 0.8912084434081088
=====
    User ID: 4
=====
Accuracy: 99.46238102734564%
Precision: 95.40371329046295%
Recall: 92.0307220576634%
F-Score: 0.9368686820856766
=====
    User ID: 5
=====
Accuracy: 98.98523229346245%
Precision: 92.94328851089017%
Recall: 84.19823468401408%
F-Score: 0.8835490038926206
=====
```

```
=====
    User ID: 6
=====
Accuracy: 98.82132229975947%
Precision: 81.31620718923268%
Recall: 98.24340026568737%
F-Score: 0.8898193534963036
=====
    User ID: 7
=====
Accuracy: 98.28371945680338%
Precision: 80.92014143487967%
Recall: 89.18103538580796%
F-Score: 0.8484999494548962
=====
    User ID: 8
=====
Accuracy: 98.76591678624149%
Precision: 92.62812856130238%
Recall: 80.39298326711102%
F-Score: 0.8607795327170829
=====
    User ID: 9
=====
Accuracy: 99.7944269956953%
Precision: 96.93589318220054%
Recall: 99.23682809353906%
F-Score: 0.9807286665809827
=====
    User ID: 10
=====
Accuracy: 99.39928164775836%
Precision: 95.89794475521873%
Recall: 94.91585765285328%
F-Score: 0.9540437388404013
=====
```

```
=====
    User ID: 11
=====
Accuracy: 99.50538280290283%
Precision: 94.68509629286912%
Recall: 96.79991440911317%
F-Score: 0.9573082700695682
=====
    User ID: 12
=====
Accuracy: 99.74158610420044%
Precision: 94.86951103043275%
Recall: 99.68967640223917%
F-Score: 0.9721988439466849
=====
    User ID: 13
=====
Accuracy: 99.21635473980861%
Precision: 86.67862089903417%
Recall: 97.69697444964069%
F-Score: 0.918585672392124
=====
    User ID: 14
=====
Accuracy: 98.936004454377747%
Precision: 82.313537822199446%
Recall: 97.94397498170204%
F-Score: 0.8945108543557351
=====
    User ID: 15
=====
Accuracy: 98.34709304126106%
Precision: 92.6844146440651%
Recall: 68.05492840808121%
F-Score: 0.7848272965879265
=====
```

```
=====
    User ID: 16
=====
Accuracy: 99.37653877321387%
Precision: 89.5817315550825%
Recall: 98.58917512550845%
F-Score: 0.9386986730442587
=====
    User ID: 17
=====
Accuracy: 94.89490211208721%
Precision: 48.46528050630503%
Recall: 91.97176694017026%
F-Score: 0.6347951006467469
=====
    User ID: 18
=====
Accuracy: 91.88906832282106%
Precision: 0.04505877519646951%
Recall: 0.036864360837037784%
F-Score: 0.0004055174223404319
=====
    User ID: 19
=====
Accuracy: 95.56726858399315%
Precision: 12.164833375968001%
Recall: 2.1590810594397367%
F-Score: 0.036672742568704425
=====
    User ID: 20
=====
Accuracy: 94.98947053297685%
Precision: 47.87819483972848%
Recall: 83.21137354261795%
F-Score: 0.6078302651412816
=====
```

```
=====
    User ID: 21
=====
Accuracy: 95.3835997099235%
Precision: 5.058365758754864%
Recall: 0.004545867806164196 5%
F-Score: 9.083572359388047e-05

Process finished with exit code 0
```

Conclusioni

Descrivi in breve di cosa parlano le diapositive successive.

TORNA AL PROGRAMMA

Conclusioni

	Accuracy	Precision	Recall	FScore
Random forest con random split	99.9%	99.9%	99.9%	0.99
Random forest con session split	99.9%	99.9%	94.1%	0.96
Grid search con random split	99.9%	99.9%	99.9%	0.99
Grid search con session split	98.8%	97.7%	95.1%	0.97
Xgboost con random split	94.9%	94.9%	94.9%	0.97
Xgboost con session split	91.8%	80.9%	83.2%	0.60
LSTM con random split	~20,15%	- N/A -	- N/A -	- N/A -
LSTM con session split	~19,47%	- N/A -	- N/A -	- N/A -

Conclusioni

Sviluppi futuri

L'applicazione risulta performante dal punto di vista dell'accuracy ma non dal punto di vista dell'esecuzione. Al fine di risolvere questo problema si è pensato ad una parallelizzazione del carico di lavoro.

TORNA AL PROGRAMMA


Thank
You!