

Artificial intelligence (AI)/ML in Packaging innovations for Drug Discovery

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Abstract

Artificial intelligence (AI) is a technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy. AI software can perform a variety of tasks, including: Content generation, Data analysis, Prediction, Process automation, Decision-making, Learning, and Problem-solving. ML/AI can help vision system experts to identify and sort false ejects from large image data sets for oral, Injectables, solids, semi-solid Doses form products “ONLINE INSPECTION”.

Key Words: oral; injectables; solids; semi-solid doses form products

Introduction

Following software are mostly using in ai & ml:

(1) Python- Software integration with AI/ML:

- ❖ Python is widely used in AI due to its simplicity, versatility.
- ❖ Rich selection of libraries for machine learning and data analysis.
- ❖ It allows developers to create intelligent systems that can learn from data, recognize patterns, and make decisions.

(2) OpenCV- Software integration with AI/ML

- ❖ Possibilities in computer vision applications.
- ❖ Enhanced object detection to sophisticated image recognition.

3) Keras -software Applications in AI/ML

- ❖ Facilitates tasks like image classification, object detection, and video analysis through easy-to-implement convolutional neural networks (CNNs).
- ❖ Ideal for applications from medical imaging diagnostics to automated manufacturing quality control.

4) TensorFlow -Software integration in AI/ML

- ❖ Natural language processing

- ❖ Computer vision
- ❖ Object detection
- ❖ Exact recognition

Steps to follow:

- Data collection from Existing Vision inspection machine
- ML/AI can help vision system experts to identify and sort false ejects from large image data sets.
- ML/AI can facilitate a streaming analytics platform for the automated vision inspection process. This **streaming analytics platform will support the vision system experts with rapid identification and remediation of both true and false ejects** from the upstream drug product unit operations.
- Vision inspection team collaborate with the data science team to develop a **prototype convolutional neural network (CNN)** to test the **ability of AI/ML models to identify true versus false ejects**.
- After the eject- and acceptable-image sets had been assembled, the team collaborate with data science team to develop a deep learning model that could classify the images using Python, OpenCV, Keras, and TensorFlow.

AI ensures Precision in Vial & PFS Inspection

- Maintaining rigorous quality control standards when mass-producing vials of liquid medicine can be challenging.
- Vials can be subject to contaminants, or cross-contamination



can occur during manufacturing. These “defects” cannot be tolerated.

- Detecting these issues is nearly impossible for the human eye, especially when vials are produced at a high rate.

Deep Learning and Edge Learning in Pharmaceutical Inspection AI's revolutionary potential lies in deep learning and Edge learning.

Deep learning

- This technology predict patterns and perform judgment-based applications.
- Deploys artificial intelligence (AI) algorithms to teach robots and machines to do what comes naturally to humans: learning by example.
- Advanced manufacturing practices for quality inspection and task automation.
- Deep learning technology transfers the logical burden from an application developer, who develops and scripts a rules-based

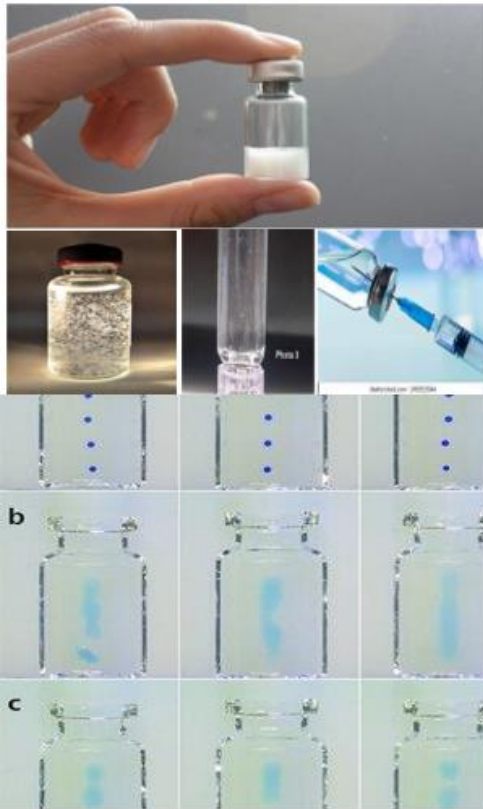
algorithm, to an engineer training the system. In this way, deep learning makes machine vision easier to work with, while expanding the limits of accurate inspection.

Edge learning

- Deploying AI models directly on the production line equipment.
- provides real-time data analysis and decision-making.
- significantly reducing inspection time.
- enhancing overall efficiency.

Silicone Oil Induced Effects in Pharmaceutical Glass Vials

Manual Inspection



Visual inspection Display Panel:



Particle inspection in liquid product



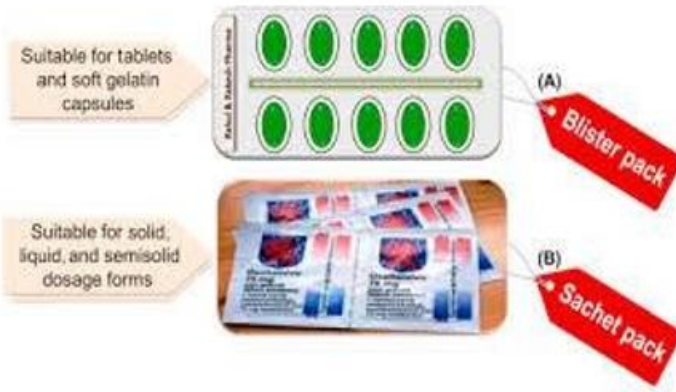
Advantages to use ai for online inspection for injectables:

- ✓ Most of the cases this has been observed in manual inspection, it is not possible to find out and eject very

small silicon oil drops and silica flex and such kind of products are not ejected from the packing line. AI/ML can solve these problems online within fraction of seconds.

- ✓ Very small back particles, glass particles, rubber stopper loose parts AI can identify and ejected those vials/PFS from packing line.

AI and ML for Solid doses Form



Optical Character Recognition (OCR)

AI-powered OCR software employs computer vision and machine learning technologies to identify the characters in images and documents, making it more accurate than traditional OCR.

Optical Character Verification (OCV)

OCV tools can also be used to verify text and numbers against expected results communicated from a PLC, printer, database or FTP server. IVS latest generation deep OCR uses Ai to read even under the most difficult conditions such as distorted letters and inconsistent surfaces with background noise.

Empty pocket and Black dots in Tablets



Color shade difference & Broken Tablets



Advantages to use AI for online inspection for solid Doses:

- ✓ In high speed blister packing line, empty pockets, black dots, broken tablets, dented capsules, open

caps, out of range coloured tablets not possible to identify 100% online. AI/ML can solve such problems and avoid market complaints.

Label and Lot Code Verification with OCR and OCV



Advantages to use AI/ML for Batch coding Inspection

- ✓ Missing of words in text, scratch on text, improper batch coding, 2D data matrix is not proper, colour share of label and carton are not proper such kind of

defective packaging materials are not possible to eject from the packing line. AI/ML can do this activities perfectly and avoid market complaints.

AI applications in Microgravity Environments in Packaging Design



Single bubble in the syringe can spoil the Eye



Cardiac problem on space station



High Radiation in Microgravity



Gold Foil Coated Vial & PFS to prevent high Radiation



Bubble Free Injection Syringe in Space a Big Challenge



- ❖ Preparation of injectable medications in a **non-micro gravity environment** simplifies removal of air bubbles within the syringe.
- ❖ This luxury is lost in micro gravity as isolation of bubbles becomes difficult due to the **absence of a force greater than the surface tension of the medication.**
- ❖ The consequence of injecting an air bubble into a crewmember is harmful.

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