

Interactive AI Demos & UI/UX

CS 203: Software Tools and Techniques for AI

Prof. Nipun Batra, IIT Gandhinagar

The "Demo" Gap

The Problem: You trained a great model. It lives in a Jupyter Notebook.

The Goal: Let stakeholders (non-coders) use it.

Options:

1. **Full Stack:** React + FastAPI + Docker + K8s. (Weeks of work).
2. **Low Code:** Streamlit / Gradio. (Hours of work).

Why Demos Matter:

- **Feedback:** Early user testing reveals edge cases.
- **Data Flywheel:** Users interacting = New training data.
- **Portability:** A URL is worth 1,000 GitHub stars.

The ML Model Deployment Spectrum

Approach	Time	Flexibility	Scalability	Use Case
Jupyter Notebook	0h	High	None	Personal use, research
Streamlit/Gradio	2h	Medium	Low-Medium	Demos, MVPs, research
FastAPI + Basic UI	1d	High	Medium	Internal tools
Full Stack App	2w+	Very High	High	Production products

Today's focus: The 2-hour solution that covers 80% of use cases.

Web App Fundamentals (Brief Primer)

Traditional web architecture:

- **Frontend** (Browser): HTML, CSS, JavaScript
- **Backend** (Server): Python, API endpoints, database
- **Communication**: HTTP requests/responses

Streamlit/Gradio simplification:

- **You write**: Pure Python
- **Framework handles**: HTML generation, CSS styling, WebSocket communication
- **Result**: Full web app without touching JavaScript

Trade-off: Less control, faster development.

Frontend vs Backend in AI Apps

Frontend responsibilities:

- User input (text, images, sliders)
- Display results (text, charts, images)
- Handle interactions (buttons, chat)
- Visual design and layout

Backend responsibilities:

- Load ML models
- Run inference
- Process data
- Business logic

Streamlit Architecture: The "Script" Model

Streamlit works differently from standard web apps.

Execution Flow:

1. User loads page -> Entire Python script runs top-to-bottom.
2. User clicks button -> **Entire script runs again from top!**
3. Frontend detects changes (diff) and updates DOM via WebSockets.

Implication:

- Variables are **reset** on every interaction.
- Need explicit **Session State** to remember things.
- Need **Caching** to prevent re-loading models.

Managing State

Without Session State:

```
count = 0
if st.button("Click"):
    count += 1
st.write(count) # Always 0 or 1. Resets every time!
```

With Session State:

```
if 'count' not in st.session_state:
    st.session_state.count = 0

if st.button("Click"):
    st.session_state.count += 1

st.write(st.session_state.count) # Persists!
```

Caching Strategies: Performance is UX

Re-loading a 5GB model on every button click = Unusable App.

1. `@st.cache_resource` : For Global Objects (Models, DB Connections).

- Loaded once, shared across all users.
- *Singleton pattern*.

2. `@st.cache_data` : For Computations (DataFrames, API calls).

- Cached based on function inputs.
- *Memoization pattern*.

```
@st.cache_resource
def load_llm():
    return AutoModelForCausalLM.from_pretrained("gpt2") # Run once
```

```
@st.cache_data
```


UX Patterns for GenAI

1. Streaming: Don't make users wait 10s for full text.

- Show tokens as they arrive.
- **Streamlit:** `st.write_stream(generator)`.

2. Latency Masking:

- Use spinners (`st.spinner`).
- Show intermediate steps ("Parsing PDF...", "Embedding...").

3. Feedback Loops:

- Add



/



Gradio: The Functional Approach

Gradio is optimized for "Input -> Model -> Output" workflows.

```
import gradio as gr

def predict(img):
    # Process image
    return "Cat"

# Auto-generates UI based on types
demo = gr.Interface(fn=predict, inputs="image", outputs="label")
demo.launch()
```

Streamlit vs Gradio:

- **Streamlit:** Full Data Dashboards, Multi-page apps, Custom Logic.
- **Gradio:** Quick Model APIs, Hugging Face Spaces integration.

Gradio Components

Input components (automatic type detection):

- `"text"` : Text box
- `"textbox"` : Multi-line text
- `"image"` : Image upload
- `"audio"` : Audio file/recording
- `"video"` : Video upload
- `"file"` : Any file type
- `"dataframe"` : Pandas DataFrame editor

Output components:

- `"text"` , `"textbox"` : Text display

Advanced Gradio: Blocks API

Interface is simple but limited. **Blocks** gives full control.

```
import gradio as gr

with gr.Blocks() as demo:
    gr.Markdown("# Image Classifier")

    with gr.Row():
        img_input = gr.Image(type="pil")
        img_output = gr.Label()

    btn = gr.Button("Classify")
    btn.click(fn=predict, inputs=img_input, outputs=img_output)

demo.launch()
```

Benefits: Custom layouts, multiple inputs/outputs, complex interactions.

Streamlit Component Types

Input widgets:

- `st.text_input()` : Single line text
- `st.text_area()` : Multi-line text
- `st.number_input()` : Numbers with validation
- `st.slider()` : Numeric slider
- `st.select_slider()` : Categorical slider
- `st.checkbox()` : Boolean toggle
- `st.radio()` : Single choice from options
- `st.selectbox()` : Dropdown menu
- `st.multiselect()` : Multiple choices
- `st.file_uploader()` : File upload

Streamlit Display Components

Text & data:

- `st.write()` : Universal display (markdown, dataframes, charts)
- `st.markdown()` : Markdown with HTML
- `st.dataframe()` : Interactive table
- `st.table()` : Static table
- `st.json()` : Pretty-printed JSON
- `st.code()` : Syntax-highlighted code

Media:

- `st.image()` : Display images
- `st.audio()` : Play audio

Multi-Page Apps in Streamlit

Structure:

```
app/
├── Home.py           # Main page (entry point)
├── pages/
│   ├── 1_Model_Demo.py
│   ├── 2_Data_Explorer.py
│   └── 3_About.py
```

Automatic routing:

- Streamlit detects `pages/` directory
- Creates sidebar navigation
- Each page is independent Python script
- Shared state via `st.session_state`

UI/UX Principles for ML Apps

1. Progressive Disclosure:

- Show simple interface first
- Reveal advanced options when needed
- Example: Basic text input → Advanced settings in expander

2. Immediate Feedback:

- Show spinners during processing
- Display intermediate steps
- Use progress bars for long operations

3. Error Handling:

- Catch exceptions gracefully

UX Patterns for AI Applications

Loading states:

```
with st.spinner("Processing image..."):
    result = model.predict(image)
```

Progress tracking:

```
progress_bar = st.progress(0)
for i, item in enumerate(data):
    process(item)
    progress_bar.progress((i + 1) / len(data))
```

Error messages:

```
try:
    result = process_input(user_input)
except ValueError as e:
```

Latency and Performance UX

Perceived performance matters more than actual speed.

Strategies:

1. **Optimistic UI:** Show result immediately, validate later
2. **Skeleton screens:** Show placeholder content while loading
3. **Streaming:** Display partial results as they arrive
4. **Background processing:** Use async for long tasks
5. **Caching:** Avoid recomputing same inputs

Rule of thumb:

- < 100ms: Feels instant
- 100ms - 1s: Acceptable with feedback

Streaming Responses (GenAI Apps)

Why stream?

- Large language models generate tokens sequentially
- Users can start reading before completion
- Better perceived performance

Streamlit example:

```
def generate_text(prompt):  
    for token in llm.stream(prompt):  
        yield token  
  
st.write_stream(generate_text(user_prompt))
```

Gradio example:

Handling Model Errors Gracefully

Common AI model failures:

1. **Input validation:** Wrong format, size, or type
2. **Out of domain:** Input unlike training data
3. **Model errors:** Crashes, OOM errors
4. **Timeout:** Model too slow

Best practices:

```
try:
    # Validate input
    if len(text) > 1000:
        st.warning("Text too long, truncating to 1000 chars")
        text = text[:1000]

    # Predict with timeout
```

Collecting User Feedback

Why collect feedback?

- Identify model failures
- Improve with human feedback (RLHF)
- A/B testing different models
- Track user satisfaction

Simple thumbs up/down:

```
col1, col2 = st.columns([4, 1])
with col1:
    st.write(model_output)
with col2:
    if st.button(
        thumbs up
    ):
        st.session_state["thumbs up"] = st.session_state["thumbs up"] + 1
```

Data Collection from Demos

Ethical data collection:

1. **Transparency:** Tell users data is collected
2. **Consent:** Add checkbox for data sharing
3. **Privacy:** Don't store PII without permission
4. **Security:** Encrypt sensitive data

Simple logging:

```
import json
from datetime import datetime

def log_interaction(input_data, output, feedback=None):
    entry = {
        "timestamp": datetime.now().isoformat(),
        "input": input_data,
```

Deployment Options Comparison

Platform	Cost	Compute	Best For	Limitations
HF Spaces	Free-\$\$	CPU/GPU	Public demos	Community visibility
Streamlit Cloud	Free-\$\$	CPU only	Streamlit apps	Limited resources
Render	Free-\$\$\$	CPU/RAM	Web services	Sleep on inactivity
Railway	Pay-as-go	Flexible	Full apps	Can get expensive
AWS/GCP	Pay-as-go	Infinite	Production	Complex setup

For demos: HF Spaces or Streamlit Cloud are best.

Hugging Face Spaces Deep Dive

What is HF Spaces?

- Free hosting platform for ML demos
- Supports Streamlit, Gradio, Docker, static sites
- Automatic HTTPS, version control
- Optional paid GPU upgrades

Deployment steps:

1. Create Space on huggingface.co
2. Choose SDK (Streamlit/Gradio)
3. Add files: `app.py` , `requirements.txt` , `README.md`
4. Push to Space repository (git)

Configuration Files

requirements.txt (Python dependencies):

```
streamlit==1.28.0  
transformers==4.35.0  
torch==2.1.0  
pillow==10.0.0
```

README.md (Space metadata):

```
---  
title: Image Classifier  
emoji:  
  
  
colorFrom: blue  
colorTo: purple  
sdk: streamlit  
python_version: 3.10
```

Best Practices for Deployment

1. Environment management:

- Use `requirements.txt` (not conda)
- Pin exact versions
- Test locally first

2. Error handling:

- Catch all exceptions
- Show friendly error messages
- Log errors for debugging

3. Resource limits:

- Set max file upload size

Streamlit Secrets Management

Local development (`.streamlit/secrets.toml`):

```
OPENAI_API_KEY = "sk-..."  
DATABASE_URL = "postgresql://..."
```

Access in code:

```
import streamlit as st  
  
api_key = st.secrets["OPENAI_API_KEY"]
```

In Streamlit Cloud:

- Settings → Secrets
- Paste TOML format
- Secrets are encrypted

Testing Interactive Apps

Local testing:

```
streamlit run app.py
```

Unit tests (for helper functions):

```
def test_process_text():  
    result = process_text("hello")  
    assert len(result) > 0
```

Integration tests (with Streamlit):

```
from streamlit.testing.v1 import AppTest  
  
def test_app():  
    at = AppTest.from_file("app.py")  
    at.run()
```

Performance Optimization

Model loading:

```
@st.cache_resource
def load_model():
    # Expensive operation
    return torch.load("model.pt")

model = load_model() # Only runs once
```

Data processing:

```
@st.cache_data(ttl=3600) # Cache for 1 hour
def load_data(url):
    return pd.read_csv(url)
```

Lazy loading:

Don't import heavy libraries at top

Accessibility Considerations

Make your demo accessible:

1. **Alt text for images:** Describe what image shows
2. **Color contrast:** Use high contrast for text
3. **Keyboard navigation:** All features should work without mouse
4. **Screen reader friendly:** Use semantic HTML/markdown
5. **Clear labels:** Describe what each input does

Example:

```
st.image(img, caption="Classification result: Cat (98% confidence)")  
st.text_input("Enter movie title", help="Search for any movie in our database")
```

UI/UX Design Principles for ML Apps

Progressive Disclosure: Start simple, reveal complexity gradually.

Example:

```
# Basic mode (default)
mode = st.radio("Mode", ["Simple", "Advanced"])

if mode == "Simple":
    prompt = st.text_input("Enter your question")
else:
    # Advanced options
    prompt = st.text_area("Enter your question")
    temperature = st.slider("Temperature", 0.0, 2.0, 0.7)
    max_tokens = st.number_input("Max tokens", 100, 2000, 500)
    top_p = st.slider("Top-p", 0.0, 1.0, 0.9)
```

Benefit: Beginners aren't overwhelmed, experts can customize.

Latency Management: Strategies

Perceived performance matters as much as actual speed

Three key strategies:

1. **Progress indicators:** Show that work is happening

- Progress bars for known-duration tasks
- Spinners for unknown-duration tasks

2. **Streaming:** Show partial results as they arrive

- Essential for LLM text generation
- Better UX than waiting for complete response

3. **Optimistic UI:** Assume success, update on completion

- Immediate visual feedback

Latency Management: Implementation

Progress bars:

```
progress = st.progress(0)
for i, item in enumerate(data):
    process(item)
    progress.progress((i + 1) / len(data))
```

Streaming outputs:

```
output_placeholder = st.empty()
result = ""
for chunk in model.stream(prompt):
    result += chunk
    output_placeholder.write(result)
```

Optimistic UI:

Error Handling Patterns for ML Apps

User-friendly error messages:

```
try:
    result = model.predict(image)
except ValueError as e:
    if "shape" in str(e):
        st.error("
X Invalid image size. Please upload an image larger than 224x224 pixels.")
        elif "format" in str(e):
            st.error("
X Unsupported image format. Please upload JPG or PNG.")
            else:
                st.error(f"
X Processing error: {e}")
except Exception as e:
    st.error("
X Unexpected error. Please try again or contact support.")
```

A/B Testing ML Demos

Test different UX variants:

```
# Assign users to variants
import hashlib

def get_variant(user_id):
    """Deterministic A/B split based on user ID."""
    hash_val = int(hashlib.md5(user_id.encode()).hexdigest(), 16)
    return "A" if hash_val % 2 == 0 else "B"

# Get or create user ID
if 'user_id' not in st.session_state:
    st.session_state.user_id = str(uuid.uuid4())

variant = get_variant(st.session_state.user_id)

if variant == "A":
    # Variant A: Simple interface
    st.title("AI Assistant")
    prompt = st.text_input("Ask a question")
else:
    # Variant B: Advanced interface
    st.title("
 AI Assistant – Powered by GPT-4")
    prompt = st.text_area("Ask a question", height=150)
    st.slider("Creativity", 0.0, 1.0, 0.7)
```

Analytics and Monitoring for Demos

Track usage patterns:

```
import posthog

posthog.init('YOUR_API_KEY', host='https://app.posthog.com')

def log_event(event_name, properties=None):
    """Log events for analytics."""
    posthog.capture(
        distinct_id=st.session_state.user_id,
        event=event_name,
        properties=properties or {}
    )

# Track interactions
if st.button("Generate"):
    log_event("generate_clicked", {
        "prompt_length": len(prompt),
        "model": selected_model
    })

    result = model.generate(prompt)

    log_event("generation_complete", {
        "latency_ms": latency
```

Scaling Demos That Go Viral

Problem: Demo gets popular, traffic spikes.

Solutions:

1. Rate limiting:

```
import time

if 'last_request_time' not in st.session_state:
    st.session_state.last_request_time = 0

def check_rate_limit(requests_per_minute=10):
    """Enforce rate limit."""
    current_time = time.time()
    time_since_last = current_time - st.session_state.last_request_time

    if time_since_last < 60 / requests_per_minute:
        wait_time = (60 / requests_per_minute) - time_since_last
        st.warning(f"
```

Version Control for Interactive Apps

Git strategies for Streamlit apps:

```
# .gitignore for Streamlit
.streamlit/secrets.toml # Never commit secrets!
*.pyc
__pycache__/
.env

# Separate config from code
```

Config management:

```
# config.yaml
app:
  title: "My ML Demo"
  version: "1.2.0"
  models:
    - name: "GPT-3.5"
```

Summary

1. **Frameworks:** Streamlit for dashboards, Gradio for quick model APIs
2. **Architecture:** Understand re-run model and state management
3. **Performance:** Cache models and data aggressively
4. **UX:** Provide feedback, handle errors, stream when possible
5. **Deployment:** HF Spaces for easy, free hosting
6. **Best Practices:** Security, testing, accessibility

Advanced Topics:

- Progressive disclosure for UI design
- Latency management (perceived performance)
- Error handling patterns

Additional Resources

Documentation:

- Streamlit: <https://docs.streamlit.io>
- Gradio: <https://gradio.app/docs>
- HF Spaces: <https://huggingface.co/docs/hub/spaces>

Inspiration:

- HF Spaces gallery: <https://huggingface.co/spaces>
- Streamlit gallery: <https://streamlit.io/gallery>

Analytics:

- PostHog: <https://posthog.com> (open-source analytics)
- Streamlit Analytics: <https://docs.streamlit.io/library/api->