A taxonomy of computer architectures

Architectures taxonomy

- We have considered different types of architectures, and it is worth considering some way to classify them.
- Indeed, there exists a famous taxonomy of the various architectures: it is well known, though it is rough and not precise (it was ceonceived back in 1966 !!): **Flynn's taxonomy** (Tanenbaum, Fig. 8.20):

Instruction streams	Data streams	Name	Examples
1	1	SISD	Classical Von Neumann machine
1	Multiple	SIMD	Vector supercomputer, array processor
Multiple	1	MISD	Arguably none
Multiple	Multiple	MIMD	Multiprocessor, multicomputer

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- Flynn's taxonomy uses two basic concepts: parallelism in *instruction* stream, and paralleism in *data* streams.
- A *n* CPU system has *n* program counters, so there are *n* "*instruction streams*" that can execute in parallel.
- A *data stream* can be thought of as a sequence of data. In a stream, each data is processed in the sequence it belongs to. There can be multiple independent streams, with the computation carried out on a stream being separate and distinct from that carried out on another stream.
- Data and instruction streams are, to a certain degree, orthogonal, and there exist 4 possible, different combinations:

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- **SISD: Single Instruction (stream) Single Data (stream)** it is the classical uniprocessor architecture, where instructions are executed one at a time on a single data stream: variables in the program being executed.
- Owing to ILP, this view if fairly inaccurate (just consider the operation of a single pipeline), and it is currently correct only for simple processors in embedded applications, such as Intel 8051.
- Intel 8051 familty processors have no pipeline, (most instructions take a single clock cycle), they issue and execute instructions in order, and have no cache.
- They are 8-bit architectures, have a clock frequency of some tens of MHz, cost10, 20 euro cents, and are by large the processor that sell the most: some 8 BILLION pieces per year !

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- They are deployed in alarm clocks, in wash machines, in microwave owens, in cordless phones, in some “electronic” toys, in some medical appliances, and so on.
- Classifying superscalar, multiple-issue processors in the SISD category is somewhat dubious, but is common practice. Actually, modern processors are the off-spring of the classical Von Neumann architecture

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- **MISD: Multiple Instruction (stream) Single Data (stream):** is this a class of architectures that makes any sense? Many authors think it does not.
- However, some argue that considering modern processors an instance of SISD architectures is less precise than ascribing them to the MISD class: the data to be processed flow from one instruction to the next as the instructions flow within the stages of the pipeline.

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- **SIMD: Single Instruction (stream) Multiple Data (stream):** the SIMD model was adopted in one of the first models of parallel architectures ever proposed, the well known Illiac IV.
- Illiac IV was designed in the mid 60's and was actually built in 1972: it cost 31 million $ (1972 $) and had a computational power of some 50 MFLOPS (the initial target was 1 GFLOP).
- Illiac IV is the most famous case of an architectural model currently almost disappeared, known as **array processor**: a huge number of identical processors that execute the same sequence of instructions on different data streams.

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- There is a second type of SIMD architectures, conceptually very similar to array processors: **vector processors**.
- Vector processors work on arrays od data, but a single processor is in charge of carrying out the operation on all elements in the array.
- These processors did have some success in the “supercomputer” arena (some CRAY models adopted this architectures), but are currently declining.

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- The SIMD paradigm has been used also within the microarchitecture of general purpose processors by extending their ISA to handle multimedia data. It the so called "**multimedia extensions**".
- But the most notable exploitation of this paradigm is currrently in the graphics processing domain, where GPU (**Graphical Processing Unit**) model has produced a specific implementation of SIMD architecture for handling multiple data streams of graphic objects.

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- **MIMD: Multiple Instruction (stream) Multiple Data (stream):** This encompasses all multiprocessor and multicomputer architectures (from dual core processors, to small UMA systems, up to clusters such as Google).
- It is worth underlining that Flynn's taxonomy is really coarse, and there are architectures that do not fit well in this scheme:
  - multithreaded processors : SISD or MIMD?
  - general purpose processors with SIMD extensions: where do they belong?

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- Flynn's taxonomy (Tanenbaum, Fig. 8.21).