5.3 Emerging Computational Technologies

As this is being written, despite the potential for many beneficial improvements, current software development practices are relatively stable. In contrast, many advances in computational technology are being explored, emerging for eminent use, or already being adopted. This section will consider the implications, such as can be foreseen, for these advances on software development practices.

Specialized Processors

Most advances in computational capabilities begin as complex software built to operate on existing general-purpose computational devices. As these advances become more fully understood, refined, standardized, and increasingly complex, the opportunity arises to create computational devices that both simplify the software and allow it to operate more efficiently. Traditionally, these advances took the form of enhancements to general purpose computing hardware or software. However, as the means for building special-purpose hardware has become more practical, such advances are increasingly being realized in purpose-built hardware devices.

(motivation: create initial solutions in software that provide a basis for a specialized hardware realization of key capabilities that streamline and reduce processing cost of specialized processing; notional result of hdw/sw codesign over time)

(software-enabled hardware: edge and interface devices embed computational hardware for hdw-sw hybrid realizations of virtualized capability)

(target sw to operate on platform of the most suitable computational devices)

Examples of such hardware have become common, some becoming viable and broadly commercialized in only the last 10 years:

- Signal (Analog-to-digital and digital-to-analog) analysis and conversion:
- Sound, audio, and speech processing:
- Motion tracking, identity, security processing:
- Display, image, graphics, touch processing:

- Image and graphics manipulation: Originally created to reduce the load on general-purpose computational elements, these provided specialized processing for rapidly and efficiently displaying visual information on display devices. These provided highly parallel "single function, multiple data" processing that relied on complex mathematical operations suited to such processing. In recent years, these processors have come to be applied to the processing of other highly parallel problems related to data mining and machine learning. This dual use of this technology has foreshadowed the realization of parallel processing capabilities in specialized hardware realizations for machine learning based on massive data analyses.
- Communications, data storage and sharing
- Environmental sensor/effectors:
- Augmented reality functions:
- AI/machine learning/data analysis functions:

(tension between specialization and integration in a hardware device, eg consider graphics processor single-to-dual use transition)

(how does this affect sw dev practices: specialized sw evolved to service that encapsulates use of specialized hdw device)

Remote and Virtualized Computing Resources

{high-perf/parallel computing (local multi-core/multi-processor node controls network process; complex predictive models/simulations (mega-data process analysis: weather, ocean dynamics)}

(how does this affect sw dev practices:)

Edge Computing Devices

autonomous and as nodes in CyberPhysical systems (connected computation and data collection by all devices)

(enabled by size- & cost-reduction in sensor-effector tech, distributed/remote computing capabilities; distributed monitoring, data collection, and control of larger environmental space; autonomously-operating devices heavily replicated & embedded in natural/artificial elements, remotely managed & controlled)

(motivation: cyberphysical systems for managing/controlling monitored environment)

(how does this affect sw dev practices:)

Mobile, Distributed, Autonomous Computing

(anywhere-anytime augmented computing => robotics)

Manufacturing Technology

(hdw-sw codesign for fabrication of customized hdw from sw spec'd models, using 3-D printing and robotics)

(how does this affect sw dev practices:)

Organic Computing

(DNA/genomic-based)

Quantum Computing

As quantum computing becomes practical, questions will arise concerning how best to develop software that defines the behavior of devices using this technology. It may be that existing software abstractions can be applied, possibly with modifications, to express and be translated into a form that defines the behavior of a quantum computing engine. Conversely, such computation may lend itself to other expressions of behavior better suited to quantum processing capabilities. Ideally, at least in the medium-term, an existing or new hybrid form of expressing behavior will suffice such that software can

be specified, with the type of hardware on which it is employed can be decided, and changed, freely. At the least, in the short-term, quantum computations may be in some cases implementable as simulations on conventional digital processors for purposes of initial verification.

(how does this affect sw dev practices: medium-term will take form of a specialized processor that enables particular capabilities for computation not feasible or sufficiently efficiently with conventional computing (characterize type of problems expected, to include encryption-related))