



University  
of Glasgow

**Thursday, 4 May 2023**

**14:00-15:30 BST**

**Duration: 1 hour 30 minutes**

**Timed exam – fixed start time**

**DEGREES OF MSc, MSci, MEng, BEng, BSc, MA and MA (Social Sciences)**

# **ADVANCED SYSTEMS PROGRAMMING COMPSCI 4089**

**Answer all three questions**

**This examination paper is an open book, online assessment  
and is worth a total of 60 marks.**

1. (a) In the early 2000s, processor design moved from emphasising single threaded performance to emphasising support for parallelism. This led to the number of processors cores per device increasing rapidly. Explain why this transition occurred. [5]
  - (b) The Rust programming language expresses the concept of ownership, and the ability to transfer ownership of data, as part of its type system. This allows Rust programs to safely pass mutable data between threads without race conditions. Other programming languages, for example Erlang, avoid race conditions by only allowing immutable data to be passed between threads. Discuss whether you think the benefit of being able to safely pass mutable data between threads in Rust is worth the complexity introduced in the type system. [5]
  - (c) The Erlang programming language adopts the “let-it-crash” approach to error handling, where responsibility for handling failures in a task is pushed out to a separate supervisor task. Discuss whether this approach to error handling is appropriate for use in systems programs, or if in-process error detection and recovery is better suited to handling errors in systems programs. Your answer should include an explicit discussion of the trade-offs between the two approaches. [10]
2. (a) A common pattern in some C programs that process binary data, for example network packet formats or compressed image or video file formats, is to write code similar to the following example:

```

struct rtp_packet {
    unsigned short v:2; /* packet type */
    unsigned short p:1; /* padding flag */
    unsigned short x:1; /* header extension flag */
    unsigned short cc:4; /* CSRC count */
    unsigned short m:1; /* marker bit */
    unsigned short pt:7; /* payload type */
    uint16_t seq; /* sequence number */
    uint32_t ts; /* timestamp */
    uint32_t ssrc; /* synchronisation source */
}

...

char *buffer = malloc(BUFLen);
if (recvfrom(fd, buffer, BUFLen, 0, &addr, &addrlen) > 0) {
    struct rtp_packet *pkt = (struct rtp_packet *) buffer;
    if (pkt->v == 2) {
        // Process packet
        ...
    } else {
        ...
    }
}

```

This example uses `recvfrom()` to read data from a UDP socket and stores it in `buffer`, a heap allocated array of bytes. It then takes a pointer to a structure of some different type,

in this case `struct rtp_packet`, and uses a cast to make it point to the contents of the buffer, allowing access as if the buffer was of that type.

Discuss what are the advantages and disadvantages of this approach, and state whether you think it is an appropriate design pattern to use in modern systems. Your answer should mention the type and memory safety implications of this technique. [10]

- (b) It has been claimed that the use of modern programming languages, with expressive type systems, can improve software security. Do you agree? Discuss and justify your answer, giving examples to illustrate key points. [10]
- 3. (a) One of the key features of systems programming languages is that they provide control over the layout of data in memory. Explain why this is important, and outline what features of the C and Rust programming languages provide this control. [10]
- (b) Rust distinguishes between shared immutable references to data (`&`) and uniquely owned mutable references (`&mut`). Explain why this distinction is made, and what benefits it provides. [4]
- (c) The design of Rust encourages programming in a largely functional style, passing immutable data and writing pure functions. Discuss whether you think a functional programming style is appropriate for systems programming, highlighting both advantages and disadvantages. [6]